ELECTRICITY METERS:

THEIR

CONSTRUCTION AND MANAGEMENT.

A PRACTICAL MANUAL FOR CENTRAL STATION ENGINEERS, DISTRIBUTION ENGINEERS, AND STUDENTS.

BY

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PREFACE.

THE rapid growth of the Electricity Supply industry during the last fifteen years has brought into action enormous numbers of Electricity Meters of many types, depending for their action on various principles. Considering the important part these relatively small pieces of apparatus play in the industry, it is surprising how little is to be found in Electrical literature devoted to them and to their construction and management. Descriptions of new meters have certainly from time to time appeared in the technical press, but apart from these very little has been written on the subject.

No attempt has been made in the following pages to even refer to many meters which have appeared, but which have from various causes not found favour. A description, however brief, of all the meters which have been tried would fill a volume of considerable size, much of which would be out of date. From a historical point of view this matter would no doubt be interesting, but from a practical one it is not so important. Only those meters have, therefore, been described which are in use at the present day or which have recently been introduced.

After a short introductory Chapter, those following are devoted to Alternating-current Meters, Continuous-current Meters, Meters suitable for both Alternating

and Continuous Current, Prepayment Meters, Double Tariff Meters and Maximum Demand Indicators, and Tram Car Meters. In each of these Chapters the Meters referred to are arranged in alphabetical order.

The latter portion of the book is devoted to TESTING arrangements and apparatus, meter testing, fixing, reading, cleaning and repairing, and meter book-keeping, and it is hoped that this portion may prove of service to those engaged in meter work generally, and especially to those about to enter this branch of the work connected with electricity supply. Many of the large electrical undertakings are provided with properly equipped test rooms, but in many instances it seems that, whilst no expense is spared on station equipment, the outlay on first-class testing instruments and convenient testing switchboards and tables is begrudged. Considering that the revenue of such an undertaking depends so enormously on the proper initial calibration and subsequent efficiency of the meters employed, this seems all the more remarkable.

In conclusion, I wish to express my sincere thanks to those firms who have kindly lent blocks for illustrating their meters; to my colleague, Mr. W. G. Shee, who has devoted much of his time and skill in producing the photographs from which many of the original blocks have been made; and to Messrs. Kelvin and James White for permission to use the tables of doubled square roots.

C. H. W. G.

LONDON, *March*, 1906.

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CHAPTER I.

INTRODUCTORY.

When electric lighting developed out of the experimental stage, to become a practical method of illumination, the energy being supplied by means of mains to numerous consumers by one supplier, or undertaking, the necessity for metering the amount of energy taken by each individual consumer became the mother of several inventions, in the shape of meters of more or less practical form. Many of these have become extinct, and only a few of the earlier types have remained in use up to the present day. Previously a certain sum was charged per lamp per annum, or per quarter, but the unfairness —both to consumer and to supplier—of this method of charging would have done much to check the growth of the electric lighting industry.

The work imposed on an electricity meter is perhaps the hardest that is put upon any electrical machine. It is erected, probably in a cellar, and kept there for four or five years or longer without receiving any attention, except an examination of the reading once a quarter by the meter reader. It is, further, expected to be accurate on all speeds, from zero to the speed corresponding to its full load, and, should it become inaccurate to an extent of 5 or 6 per cent., it is liable to be looked upon as a terrible offender (particularly by the consumer, if the inaccuracy be against him).

It is sometimes put forward that the accuracy of a clock or watch remains good for many years, and therefore why should

not a meter be made to have the same accuracy? The work of a clock, however, is very different. It works at a uniform speed with a strong power to drive it, whereas in a meter the power for driving is kept down as low as possible and is generally very small.

The function of an electricity meter is to measure the amount of electric energy consumed in certain translating devices, such as lamps, motors, heaters, cooking apparatus and the like.

When a continuous-current of electricity passes in a circuit, work is done in that circuit, and the practical unit by which the amount of work done is expressed is the joule. The joule, being the work done in one second when a current of one ampere flows under a potential difference of one volt, or one watt for one second, is a small unit from an electrical engineering point of view, and, therefore, the Board of Trade Unit (B.T.U.) has been taken as the commercial unit by which electric energy is bought and sold in the United Kingdom, and is equal to 1,000 watt-hours, or one kilowatt-hour. The Board of Trade unit is, therefore, 3,600,000 times as large as the joule.

In continuous-current circuits the energy consumed in a circuit expressed in watt-hours (or thousandths of a B.T.U.) is always the product of current in amperes, pressure in volts, and time for which the current flows in hours.

In an alternating-current circuit the current and pressure at each moment are varying, and their variations may be represented by sine curves. Their effective, or virtual values, are equal to the square root of the mean of the squares of all the instantaneous values. If the two curves indicating the instantaneous values of the current and pressure vary together —that is to say, if they are both positive, or both negative, during the same intervals of time—then the product of their virtual values and the time is equal to the energy supplied to the circuit, which would be the case in a non-inductive circuit. The energy measured in this way would be the equivalent of that if a continuous current were flowing. Should the circuit be inductive or possess capacity, the current curve will lag behind or lead the pressure curve by an amount depending on the inductiveness or amount of capacity in the circuit. The

lag or lead is usually expressed as an angle, the whole period representing 360 deg.

In such circuits the product of the effective or virtual values of amperes and volts does not give the mean rate of working, or true watts, as the current for some part of the time in each complete period is of opposite sign to the pressure; hence their product is negative during these intervals, which means that power is being returned from the circuit. The true power is in such a case given by the expression

$$W = A_v \times V_v \times \cos \alpha,$$

where α is the angle of lag.

Thus the energy supplied to the circuit in Board of Trade units is

$$U = 1000 \, (A_v \times V_v \times \cos \alpha \times H),$$

where H is the number of hours during which a current A_v amperes flows at a pressure V_v volts through a circuit the power-factor of which is cos α.

Electrical meters, or more correctly, electrical integrating meters, may be divided into two classes. They are (1) Watt-hour meters, and (2) Ampere-hour meters. Those of the first class register, or should register, the true energy supplied through them. Mathematically, they find the value of $\int_{t_0}^{t_1} CV dt$, where C and V are the various values of the current and pressure between the times t_0 and t_1. In the case of alternating-current meters, C and V are the virtual amperes and volts respectively, and the expression under the integral must be multiplied by the "power-factor" of the circuit. For the second class the integral becomes $\int_{t_0}^{t_1} C \, dt$, the pressure being assumed constant at the "declared pressure." If this declared pressure is not kept, then with an ampere-hour meter the number of Board of Trade units for which the consumer would be charged would be too high or too low, according as to whether the supply had been at lower or higher pressure than the "declared."

Ampere-hour meters possess the advantage of simplicity of connections, as they are inserted in one main only, whereas watt hour meters either require both mains to be taken into the meter, or one only, and a tapping from the other to supply the current for the shunt winding.

In the case of alternating-current circuits, ampere-hour meters should only be used when the circuits are practically non-inductive, such as those containing incandescent lamps, as it is in such circuits only that the consumption of energy can be arrived at with any accuracy by means of an alternating-current ampere-hour meter. Frequently the dials of ampere-hour meters are stated to read Board of Trade units at a constant pressure, but although the pressure may be constant, their readings would always be too high when used on inductive circuits, owing to the fact that they cannot take any account of the lag of the current behind the volts. Their inaccuracy on inductive circuits becomes greater and greater as the lag increases.

If employed on such circuits, their readings would indicate the "apparent" units instead of the "true" units consumed. To obtain the true units it would be necessary to multiply the consumption as shown by the meter by a constant, this constant being the cosine of the angle of lag (or power factor). This would only be possible where the power factor was unvariable, Watt-hour meters are much more suitable for alternating-current circuits, and are almost always used now, even on non-inductive circuits, the exceptions being in small installations of a few lamps.

As will be seen later on, however, some alternating watt-hour meters are quite as unsuitable as ampere-hour meters for the metering of energy supplied to inductive circuits, unless properly designed for such work.

Ampere-hour meters are only suitable for one kind of current, but several watt-hour meters have been put on the market which are equally suitable for alternating and continuous-current circuits without any mechanical alteration, and in some cases without special calibration. This—although not an important feature to suppliers of current who generate only one kind, and do not propose to change their supply in future to another kind—is a distinct advantage in more ways than one to those who supply both alternating and continuous current, or to those who intend to change the supply from alternating to continuous, or vice versa. Meters form a large item in capital outlay, and the wholesale "scrapping" of a certain make owing to its unsuitability for working on the new supply would mean a great expense.

Another point, although by no means so important, is the number of meters in stock, which would be consequently increased. Many sizes of meters have to be stocked, and it is very desirable to keep down the stock—which is idle capital—as much as possible. In order to avoid delay in supplying meters from the test room for erection, it is always necessary to have a supply in all sizes tested. There must of necessity also be several which are untested, and, after the undertaking has been running some time, a further stock, composed of defective meters brought in from time to time from circuit, which cannot always be repaired at a moment's notice, will further swell the store. In a large electric lighting undertaking, with some thousands of meters, there must necessarily be a number constantly being returned from the above cause, as also on account of consumers increasing their lamp connection. It is worth while to overhaul, or at any rate to inspect carefully, all meters that have been returned to the testing department after having been out on circuit for some time.

Meters may also be classified according to the principle upon which they work, thus: Clock meters, electrolytic meters, motor meters. Clock meters form the smallest class, there being practically only two examples in commercial use at the present day. They depend either upon the difference of the rates of two separate clocks (such difference being caused by the energy passed through them), as in the Aron meter, or on the rate of oscillation of the escapement wheel (caused by the current), as in the Mordey-Fricker meter.

Electrolytic meters, as their name implies, depend for their action on electrolysis. Water is decomposed into its gases, or copper is transferred from one copper plate to another, both being in a solution of copper; or mercury is precipitated out of a solution of a mercurous salt. This class is confined to continuous-current circuits up to the present, although attempts have been made to produce electrolytic meters for alternating working, but so far without success.

Motor meters form by far the largest class. In these a small but definite fraction of the total energy which they are to measure is used to work a motor, to which is attached a train of wheels for recording the number of revolutions of the motor. The speed being made proportional to the energy

passed, the indices on the train may be made to indicate directly the kilowatt-hours taken by the consumer.

Probably the most advantageous classification for the purpose of description, however, is to divide meters up according to the work for which they are suitable, thus:—

(1) Meters suitable for alternating-current supply,

(2) Meters suitable for continuous-current supply,

(3) Meters equally suitable for both alternating and continuous-current supply,

and in this way it is proposed to describe them in the following chapters.

CHAPTER II.

ALTERNATING-CURRENT METERS.

Meters suitable for use on alternating-current circuits only mostly depend for their working on motion being produced by alternating magnetic fields acting on a disc or cylinder of metal. They comprise the following four principal parts :— (1) A registering train, (2) the moving portion, or rotor, (3) a driving combination, composed of an iron core with series and shunt coils, (4) a Foucault brake.

The registering train gears with a worm or pinion on the main spindle, and thus records the number of turns made by the moving part; a definite ratio is fixed between the first dial and the main spindle, so that the readings of the dials may be made equivalent to the number of Board of Trade units transmitted. The moving portion consists of a flat disc or bell of copper or aluminium, forming the rotor, supported by a vertical spindle through its centre, which rests upon a jewelled footstep bearing, and is held in position by a small bearing at its upper end. In this type of meter the mechanical friction may be kept low owing to the lightness of the moving portion, and to the absence of the necessity for commutation. This, coupled with the ease with which the acceleration can be prevented above the desired amount by means of the eddy-current brake, avoids the necessity of any mechanical contact with the moving part, with the exception of its top and bottom bearings and the point where the motion is transmitted to the registering train. The action of all meters of this class is the same, the differences between the various types being those of design, construction and workmanship.

The motor is in reality a two-phase asynchronous motor, capable of being worked on a single-phase two-wire circuit, a torque being produced by a magnetic field which varies in intensity and alters in position continually, acting on the fields set up by eddy currents which are generated in the rotor by the impressed field.

The shifting, or rotating, field is really the resultant of two fields, one of which is due to the main coil or coils through which the current consumed by the lamps or other apparatus passes, and the other to the shunt current. The main coils are of low resistance and few turns, and are as non-inductive as it is possible to make them; consequently the current is practically in phase with the pressure if the load be incandescent lamps or other non-inductive load. The shunt circuit is made as inductive as possible, so that the current through it lags nearly 90 deg. behind the impressed voltage, and consequently by almost the same amount behind the main current.

In order that an induction watt-hour meter may be a true energy meter on loads of varying power factor, and especially on very inductive loads, it is necessary for the fluxes due to the main and pressure coils to be in exact quadrature. As the main current is bound to have a slight lag, passing as it does through a coil, and as also the shunt current cannot be made to lag 90 deg. behind the impressed volts (for the shunt coil must have some resistance), the meter, although capable of being made to register non-inductive loads accurately, would register too little if used on circuits of power factor less than unity if made without any compensating device. Its armature would cease to move at all on a load the power factor of which was equal to the cosine of the angle of lag between the main and shunt currents, and it would rotate backwards, giving a negative value for the consumption on highly-inductive circuits in which the power factor was less than the above value. It is not, however, essential that the currents in the shunt and main coils be displaced in phase by 90 deg. so long as the magnetic fluxes are so displaced. Certain devices are, therefore, introduced in order to attain this end, so that the final result is that a resultant flux is produced which is in quadrature with the one not acted upon by the compensating device. Under such conditions the torque

exerted upon the disc is proportional to the cosine of the angle of the lag of the main current, and is also proportional to the product of shunt and series fluxes, which, in their turn, are proportional to the currents causing them; consequently, the torque varies directly as the true power transmitted, or as $C \times V \times \cos \phi$, C and V being the virtual current and voltage.

In order that the shunt current may be proportional to the impressed voltage, it is necessary that the iron be not too highly magnetised.

The two fluxes at 90 deg. displacement may be imagined to combine into one resultant flux, which acts on the disc or armature, and the way in which this flux alters in position may be followed by analysing the conditions which exist at different times during one period. Thus, if the two curves

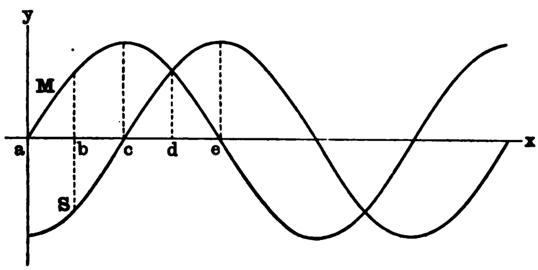

FIG. 1.

M and S represent the two fluxes (Fig. 1), due to the main and shunt currents respectively, and if diagrams be drawn of the stationary portion of the motor indicating the polarity of the iron circuit at certain instants, it is easy to see how the resultant flux shifts, and how, together with the fluxes due to the eddy currents generated by it in the disc, the necessary torque is obtained.

The two curves are represented at a phase displacement of 90 deg., corresponding to the condition of non-inductive load. The flux above *ax* is considered positive, and below *ax* negative. Starting at a time, *a*, when the series flux is zero, the shunt flux is at a negative maximum and the iron circuit (Fig. 2) is magnetised as a ring, the left-hand pole being a north and the right-hand one a south; the lower vertical limb is not magnetised at this moment, so that the flux passes across the

vertical air-gap, as indicated by the dotted lines, and there is only a slight leakage across the horizontal air-gap. At the time *b* (Fig. 3) the shunt flux is still negative, but the main flux is rising in a positive sense; thus the polarities of the upper poles are still the same, but the vertical limb now has a flux in it, the upper end being a north pole. Therefore at this

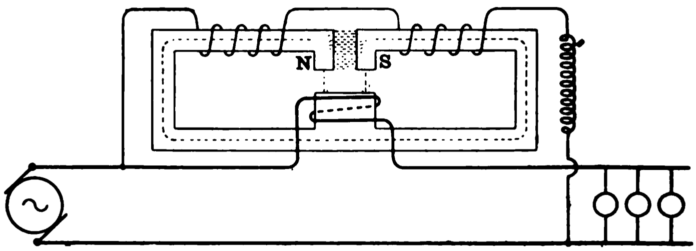

FIG. 2.

instant there is a flux in the horizontal air-gap between the right-hand pole and the pole of the vertical limb, as well as across the vertical air-gap. By the time *c* is reached (Fig. 4) the shunt flux has decreased to zero and the main flux is spread across the horizontal air-gap, the two upper poles being south and the lower one north, and there is only a slight

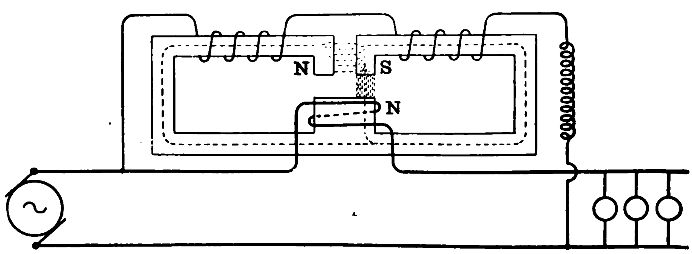

FIG. 3.

leakage across the vertical air-gap. At time *d* (Fig. 5) the shunt flux has risen, so that the left-hand pole is south and the right-hand one north, the flux in the vertical limb still remaining, although diminished in strength; so that the flux in the horizontal air-gap has now shifted to the left, and is between the left-hand and lower poles, and also between the two top

poles. Coming to *e* (Fig. 6), which is the time of one alternation, or half a period, the main flux has become zero, the shunt flux being a positive maximum; consequently the flux passes through the vertical air-gap as at time *a*, but in the opposite direction, the left-hand pole now being south and the right north.

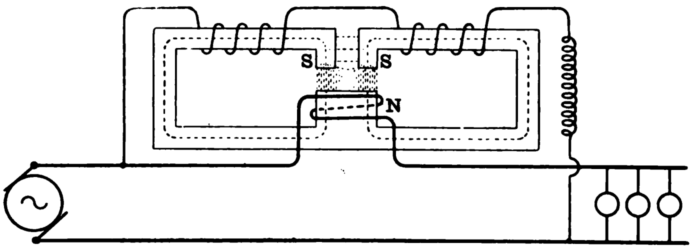

FIG. 4.

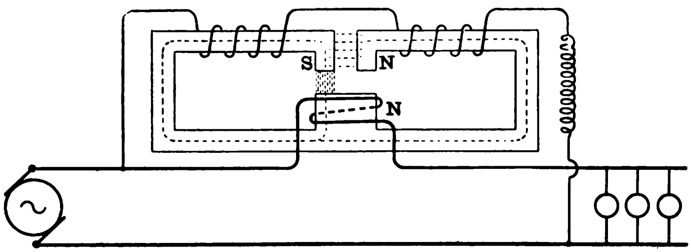

FIG. 5.

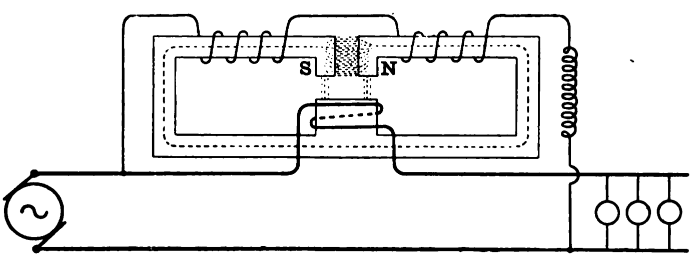

FIG. 6.

For the other half period the same changes take place, the only difference being that the polarities are the reverse at the corresponding intervals of time, the flux still passing from right to left. These same changes take place during each

period, so that the effect is that the flux in the horizontal air-gap gradually changes from zero to maximum, starting on the right and finishing at zero on the left, alternation by alternation.

Fig. 7 shows the stationary portion of the motor in plan with the disc in position. The arrangement is that adopted by the Westinghouse Company in their integrating wattmeter. The varying resultant field generates eddy currents in that portion of the disc lying in and near the horizontal air-gap, and the action between the fields created by the eddy currents and the field which induces them produces the torque which causes the disc to rotate.

Reference has been made to compensating devices for creating the 90 deg. phase difference between the main and shunt fluxes when the load is non-inductive. The compensation may

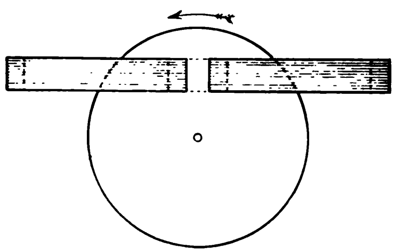

FIG. 7.

be effected by (1) causing a resultant shunt flux which lags slightly behind that produced by the shunt winding, or (2) by producing a second main flux by means of a coil wound oppositely to the first and possessing more self-induction than it.

Suppose in Fig. 8 the flux due to the main coil be represented by MF and that due to the shunt coil by SF_1, lagging by an angle, a, behind MF (a in practice is usually between 70 and 80 deg.). If a second shunt winding is placed on the shunt core, having in series with it a non-inductive resistance in order that its self-induction may be small compared with that of the first one, it can be so adjusted as to produce a flux SF_2, so that SF_1 and SF_2 produce a resultant RF, which lags 90 deg. behind the flux MF due to the main coils.

As in practice it would not be desirable to have two shunt windings, on account of the extra cost and the increased shunt

loss, the same effect is usually produced by winding closed secondary coils on the shunt core, these being insulated wire or simply copper rings, and vanes in the air-gap, in which secondary currents are generated. These coils or rings sometimes have resistance in their circuit, and final adjustment is made by varying this resistance. The disc itself also produces some effect.

In the second case compensation is obtained by a second main coil, usually in parallel with the first but wound oppositely. If in diagram 9 MF_1 and SF represent the main and shunt fluxes produced without compensation, and if MF_2 be the flux produced by the added coil, which is wound in the reverse direction, the resultant main flux MR is created, which will be

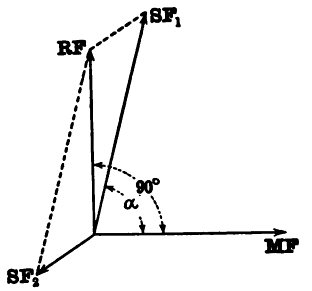

FIG. 8.

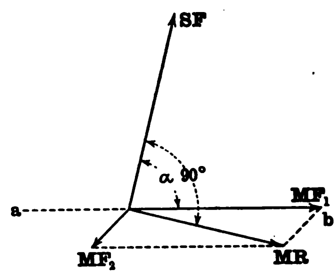

FIG. 9.

90 deg. ahead of SF when the two main circuits are correctly adjusted. From the diagram it is apparent that the circuit which produces MF_2 must have greater self-induction than that which produces MF_1, for if their self-inductions were equal, MF_2, and consequently the resultant MR, would all be in the line *ab* with MF_1, and no difference would be produced in the angle α. The circuit producing MF_1 usually includes an adjustable resistance, by which the final regulation is effected.

In practice induction motor meters are rarely quite accurately compensated, and, indeed, this is not absolutely necessary, for they are seldom called upon to work on circuits of lower power factor than 0·5. They may be found to be either under compensated or over compensated. If a meter which

is found to be correct on a non-inductive load be tested on an inductive one, and is found to under-register, it is an indication that the angle between the fluxes has not been altered sufficiently. If, on the other hand, the meter is found to over-register on the inductive load, the compensation has been overdone, and to correct this it would be necessary to reduce the effect of the compensating flux.

The Foucault or eddy-current brake is now so well known that it hardly needs description. It is a most important factor in motor meters, being made use of in the majority of meters of this class.

A disc of metal rotates in the field of a permanent magnet, and in consequence of the movement eddy currents are generated in the disc. The torque thus created is proportional to the speed, and therefore prevents acceleration after the disc has obtained a definite speed.

This form of brake is so simple, yet so perfect, that no better can be wished for, and the only point against it is the uncertainty of the strength of the magnets remaining constant. To ensure uniformity in the strength, it is important that the magnets be made of a very hard steel and tungsten alloy; that their length and section should be great compared with the length and area respectively of the air gap, so that a strong flux may be maintained; that they be properly aged artificially, so that after the ageing processes they are left at just the right strength which the quality of the alloy is capable of retaining permanently; and, finally, that the air-gap does not alter by the magnet tending to warp, and so opening out or closing up the air-gap by a slight amount. A very small alteration in length of the air-gap makes a great difference in the brake torque and, consequently, in the speed of the meter.

The Aron Induction Watt-hour Meter.—This meter, which is known as the "Aron Motor Meter," to distinguish it from the clock meters invented by Dr. Aron, is shown in Fig. 10 with its cover removed. The moving portion consists of a vertical steel spindle, the base of which is hardened and polished, and rotates on a jewelled footstep bearing. Near the lower end of this spindle an aluminium disc is fixed which forms the rotor and brake disc, being driven by the stationary portion of the

motor seen on the left of the figure, and retarded by the field of the horseshoe magnet, which is clamped to a lug standing out from the back of the meter. In this instance the whole of the magnet is above the disc, with a yoke—which is adjustable—fixed underneath.

The motive part, as will be seen from the diagram Fig. 11, consists of a horseshoe electromagnet built of laminated iron stampings carrying the two shunt bobbins. Below the shunt coils, the laminations L, by nearly touching the vertical limbs of the horseshoe, form a nearly-closed magnetic circuit through the shunt coils, causing the current in them to lag considerably

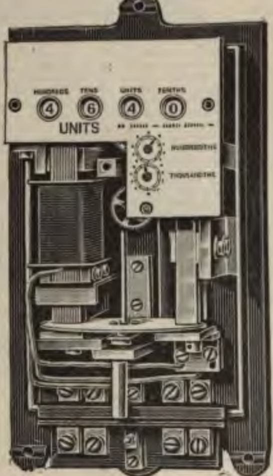

FIG. 10.—ARON INDUCTION MOTOR METER (COVER REMOVED).

behind the impressed volts. Further lag in the flux is in this instance caused by the short-circuited coils AA, which, in reality, are formed out of sheet metal with square holes to enable them to be passed on to the shunt poles. These form the compensating device to enable the meter to be used on inductive loads. The permanence of the value of the constant for loads of varying power factor, of course, depends on how accurately the compensation has been made in individual meters. The main coil is situated between the two shunt-poles, and the resultant shifting flux, which produces the driving

torque, can be investigated, as in the previous example. A worm at the upper end of the main spindle transmits its motion to a train of wheels, which terminates in the counting train, which indicates the consumption in B.T. units in plain figures. These figures are seen through circular holes in the front plate of the train, and only one figure is visible through each opening at a time, making the readings extremely simple. Fig. 12 is a view of the counting train. A is the opening corresponding to the units per division dial, whilst the $\frac{1}{10}$ths

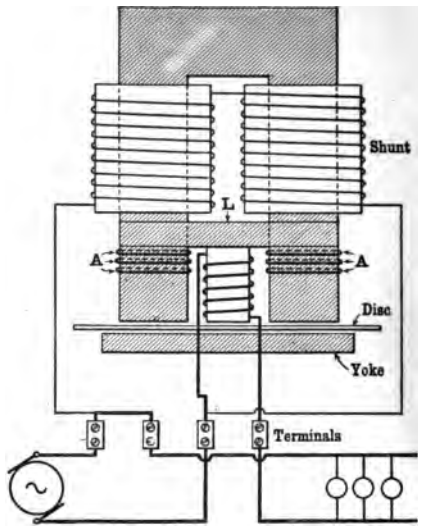

Fig. 11.—Diagram of Motor of Aron Meter.

dial is replaced by the opening B. Behind the top plate, in which are these holes, the circular discs, with the digits 0 to 9 equally spaced on them, are mounted one on each spindle. The disc behind B, when driven by the main spindle, turns with a continuous motion, and gradually winds up a hair spring (C), until, when zero is just coming into position, a pin releases a catch, allowing the hair spring to unwind, thus turning a two-toothed cog, consisting of a circular disc, having two teeth, as seen at W. The teeth, engaging with the wheel with which they gear, turn the disc

on this spindle one division, thus bringing the next number into view instantaneously. The disc locks the wheel, except when the teeth are turning it. Each spindle has a similar double-toothed disc, which engages at the proper time with the toothed wheel (such as the one shown at W in Fig. 12) on the next higher spindle. The advantages of this type of train are the simplicity with which the reading is taken and the impossibility of having intermediate positions, as in the ordinary cyclometer trains; the numbers springing into position instantaneously enable a definite reading to be always visible. The one drawback of this type of counting train is that the work put on the main moving part is variable, according to the extent to which the spring is wound. It is

FIG. 12.—COUNTING TRAIN, ARON MOTOR METER.

necessary that the spring be sufficiently powerful, with a large factor of safety, to turn all the wheels of the train simultaneously when it is released. At low loads the speed of the motor is affected according to the extent to which the spring is wound. Tests on a sample, with the spring nearly fully wound, and with it unwound, showed a difference of 4 per cent. at $\frac{1}{20}$th load, but the amount seems to be variable.

The Aron meter possesses a rather low torque, its full load value being about 1 gr.-cm. The speed is somewhat higher than is usual in this class of meter—viz., two revolutions per second at full load. The weight of the rotor and spindle together is 24 grammes, which is a medium figure for meters

of the induction-motor type. Adjustment for high loads is made by raising or lowering the yoke of the permanent magnet, and so increasing or decreasing the brake torque. For low-load adjustment the yoke of the motor may be turned slightly about the axis of its fixing screw. A forward starting torque is obtained by turning this yoke very slightly in a counter-clockwise direction (looking down from above). If turned in the opposite direction from the point of neutrality a backward starting torque is obtained.

The "Bat" Meter.—Fig. 13 shows a view of the "Bat" meter, which is also shown diagrammatically in Fig. 14 with

Fig. 13.—Bat Meter, with Covers removed.

the dial, train and top bearing removed. This meter is provided with a neat clamping gear. The screw L (Fig. 14) when unscrewed allows the collar P to rise and lift the spindle off the jewel. Referring to Figs. 13 and 14, the brake magnet is seen on the left, and the stationary portion of the motor on the right; the disc F (which is of copper) being just under

the registering train. The adjustment of the meter at high load is rendered very easy, and is done by screwing or unscrewing the milled-headed iron screw V, after having

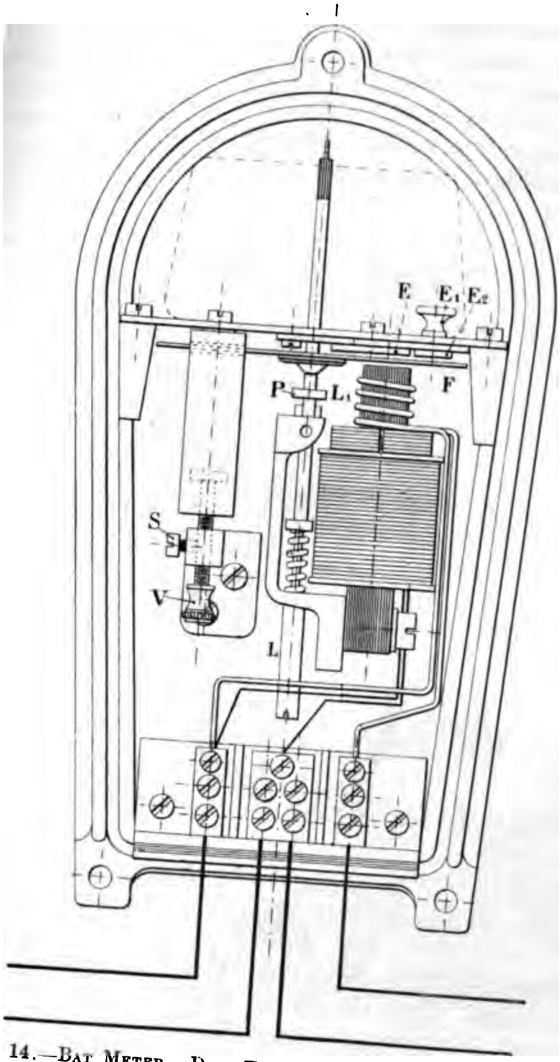

FIG. 14.—BAT METER. DIAL TRAIN AND TOP BEARING REMOVED.

loosened the clamping screw S. The screwing up of V increases the leakage or reduces the magnetic field of the brake magnet passing through the disc by making a second path for it through V and the back plate (which is of iron) to the top pole of the magnet. In this way a very delicate adjustment can be made to the brake field. Should the curve require raising or lowering at low load, this is easily done by moving the iron screw E2 (Fig. 14) forward or backward as required by means of the knob E1. If E1 is brought forward the speed will be increased.

FIG. 15.—STATIONARY PORTION OF MOTOR OF BAT METER.

The motive part is seen in Fig. 15. The two shunt coils are wound on a U-shaped iron core, the upper ends of which are split to form two poles. A laminated yoke is placed above the shunt coils, there being small air-gaps between this yoke and the core. Upon the four horns of the core are wound the series coils in reversed directions (Fig. 15), thus causing a time lag in the fluxes through the two horns of each pole. The

resultant shifting field in this meter passes twice through the disc, once at each pole. It starts from the first and third horns and shifts to the second and fourth, when it again starts at the first and third, and so on, passing up through the disc along the iron bar E (Fig. 14) and down at the other pole. The meter possesses a fair torque for this class of meter, it being about 2·3 gr.-cm. at full load. The moving part is relatively heavy, viz., 85 grammes, the weight being due to the rather large copper disc used. The curve of the meter on non-inductive load is a fairly straight line, drooping about 1 per cent. at full load. On inductive load of power factor 0·44 a difference of 2·6 per cent. has been found, the meter under-registering, as would be expected. The starting current is low. The shunt current of 100-volt meters is 0·06 amperes, and, assuming the lag of this current to be 80deg., the true watt loss in the shunt circuit would be 1·04 watts. Single-phase meters of this make are made up to 500-amperes capacity and for pressures up to 300 volts. For circuits above 300 amperes series transformers are employed and above 300 volts potential transformers, the meter used in conjunction with them being a 100-volt 10-ampere one.

Two and three-phase meters are also made; they are somewhat similar to the single-phase meter, but are provided with two driving portions and an additional disc, one of the discs being used as the armature and the second as the brake disc. The Bat meter is made in France and Switzerland. The workmanship is all that can be desired. The watt-hours* per revolution of the disc is marked on the name-plate of each meter and a number, which, when multiplied by 500, is the watt-seconds per revolution, is stamped on one of the gear pillars.

The Brush-Gutmann Meter.—The Brush-Gutmann meter is another example of the induction-motor type of integrating wattmeter. It is made in America, and its design and workmanship are good. Its case is composed of an iron box with an aluminium cover containing the necessary windows for reading

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* This constant is incorrectly called the watts per disc revolution on the meter.

the dials and inspecting the disc. The case fits on to the rim of the cast-iron box and is cemented round, forming a dust-and-damp tight joint. Fig. 16 illustrates the meter with its cover off, and shows the permanent magnet of the brake, which, as will be seen, is of a very good form for remaining permanent. The bracket on which this magnet is clamped is provided with

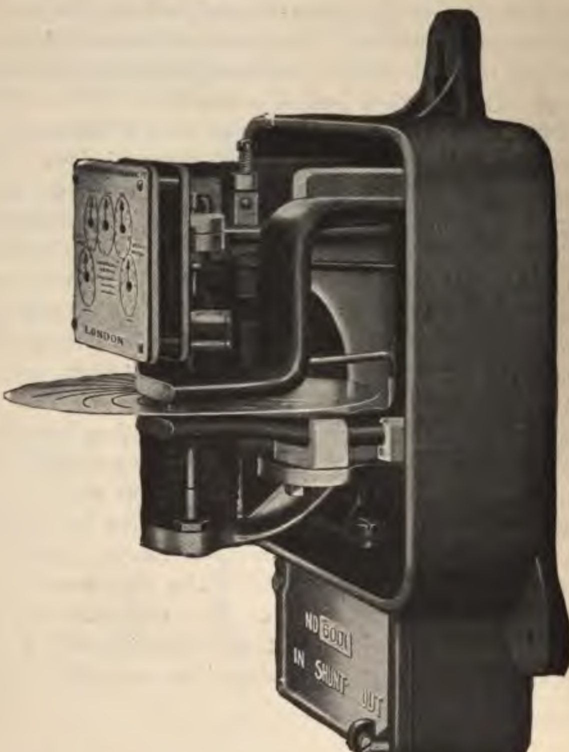


FIG. 16.—BRUSH-GUTMANN METER, WITH COVER REMOVED.

slots for the clamping screws, which enable the magnet to be shifted towards the edge of the disc, or in the other direction for calibrating at high loads. In all meters where the magnet is shifted to alter the speed, it will be easily seen that, whenever the disc extends beyond the air-gap, the speed is reduced

by bringing the magnet towards the edge of the disc, causing the brake to work at a greater leverage. Where, however, the air-gap extends beyond the edge of the disc, moving the magnet outwards reduces the lines through the disc and thus increases the speed.

The rotor is different to those of other meters in that it is slotted in spiral lines (*see* Fig. 16). It is claimed that by

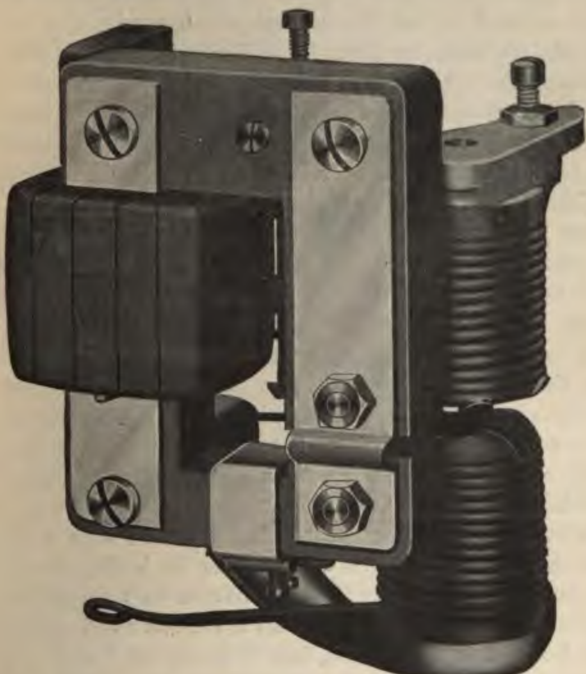


FIG. 17.—STATIONARY PORTION OF MOTOR OF BRUSH-GUTMANN METER.

so slotting the disc a higher torque is obtained. The stationary portion of the motor is shown in Fig. 17. The core is composed of two parts, the main portion and the "bridge," which is the portion below the disc. The magnetic circuit, therefore, has two air-gaps, one in which the disc rotates and another at the back which prevents the bridge being in actual magnetic contact with the main portion. The shunt coil is placed on

of the induction-motor type. Adjustment for high loads is made by raising or lowering the yoke of the permanent magnet, and so increasing or decreasing the brake torque. For low-load adjustment the yoke of the motor may be twisted slightly about the axis of its fixing screw. A forward starting torque is obtained by turning this yoke very slightly in a counter-clockwise direction (looking down from above). If turned in the opposite direction from the point of neutrality a backward starting torque is obtained.

The "Bat" Meter.—Fig. 13 shows a view of the "Bat" meter, which is also shown diagrammatically in Fig. 14 with

FIG. 13.—BAT METER, WITH COVERS REMOVED.

the dial, train and top bearing removed. This meter is provided with a neat clamping gear. The screw L (Fig. 14) when unscrewed allows the collar P to rise and lift the spindle off the jewel. Referring to Figs. 13 and 14, the brake magnet is seen on the left, and the stationary portion of the motor on the right; the disc F (which is of copper) being just under

the registering train. The adjustment of the meter at high load is rendered very easy, and is done by screwing or unscrewing the milled-headed iron screw V, after having

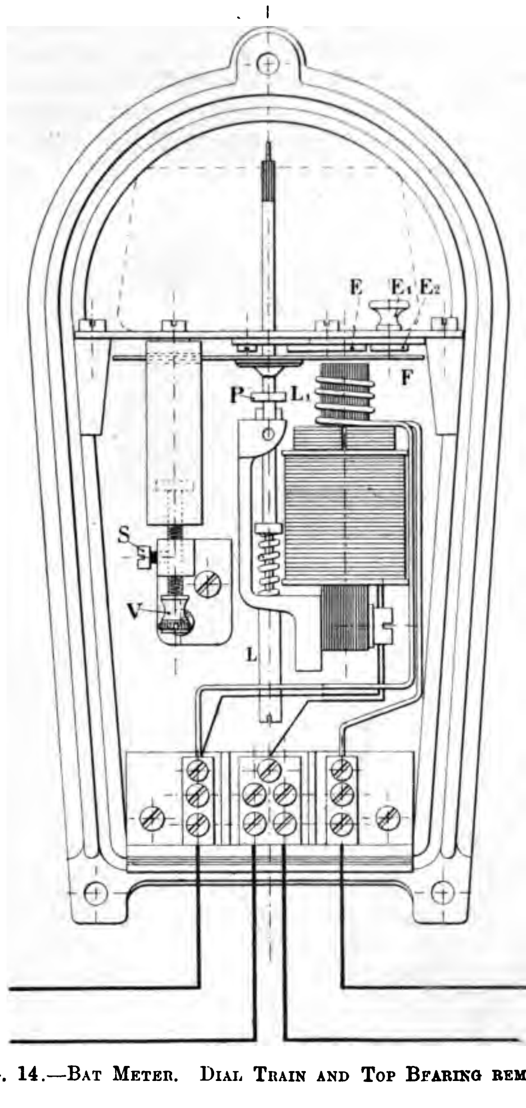


FIG. 14.—BAT METER. DIAL TRAIN AND TOP BEARING REMOVED.

The motive part of the F.E.G. meter is shown diagrammatically in Fig. 19, and that of the F.E.M. in Fig. 20. These

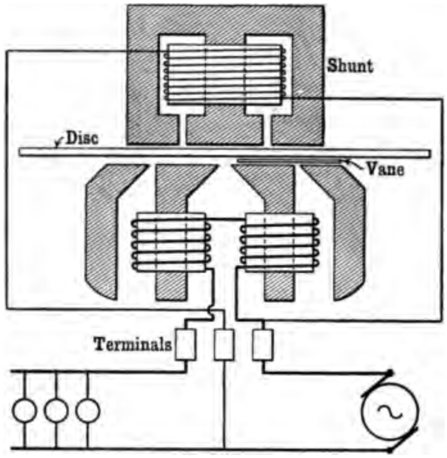


FIG. 19.—ECLIPSE F.E.G. METER. DIAGRAM OF MOTOR.

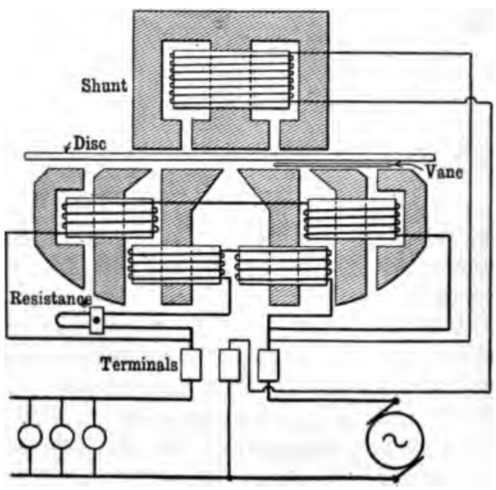


FIG. 20.—ECLIPSE F.E.M. METER. DIAGRAM OF MOTOR.

diagrams are taken looking at the backs of the meters. By comparing the two diagrams it will be seen that the compensated

meter is somewhat more complicated, having two more main coils. Of the two, however, it is to be recommended, as the F.E.G. was found to have a constant 50 per cent. too high (meaning that the meter under-registered) on a load the power-factor of which was as high as 0·8. It would thus be very risky to send out such a meter, for the consumer might add inductive apparatus to his non-inductive load at any time. The F.E.M. meter, from tests made by the Author, has been found to differ only by about 3 per cent. on a power-factor of 0·5. Short-circuiting through a fuse of double the ampere capacity seems to have no effect on the constant. The torque of these meters is rather low, being about 1 gr.-cm. at full load. The moving part is extremely light, its weight being 15 grammes, which is the lightest moving system of any induction motor meter which has come under the notice of the Author. But if additional friction appears in the registering train the constant is greatly affected owing to the lowness of the torque, and in some measure to the fact that, with so light a moving part, the friction of the counting train becomes a more important factor in the total static friction of the meter.

The meters can now be had with the ordinary dial trains. These are a great improvement on the cyclometer trains, in which it is very difficult to detect faults. Some trouble has been caused in this direction.

The low-load adjustment may be effected by moving the vane (*see* Figs. 19 and 20) to the right or left. The speed is increased by moving the vane nearer the spindle, and, consequently, the reverse effect is produced by moving it the other way. Alteration of the vane may affect the high-load speed if much adjustment is necessary, but in a much smaller degree. The action of the flux on the vane produces a torque which may cause the meter to run on its shunt if made too strong. To prevent this, a very small piece of iron is let into the disc, so that when the iron gets between the poles of the brake magnet it is held there magnetically, and thus prevents creeping.

The meters are made in various sizes up to 50 amperes. Their starting currents are good, being about one-hundredth of full load. The full-load drop varies from 1 volt on a 2½-ampere meter to 0·1 volt on a 50-ampere meter. The

shunt current of 200-volt meters is about 0·018 ampere, the true watts being 2 watts, $\cos \phi$ for the shunt circuit is 0·556, which makes the lag angle 56 deg.

The Ferranti Alternating-current Meter.—The Ferranti alternating-current meter is an integrating watt-hour meter of the induction motor type of a design which differs considerably

FIG. 21.—FERRANTI ALTERNATING-CURRENT WATT-HOUR METER, WITH COVER REMOVED.

in appearance to those previously described, as will be seen by referring to Fig. 21 (which shows the meter with its cover removed) and to the sectional drawings, Fig. 22. The dial plate, which is porcelain faced, is, in consequence, very bold. The train of wheels eventually gears in the usual way with the main spindle, which carries an aluminium disc D (Fig. 22), the

latter acting as the rotor of the motor and the brake disc, passing at the back through the air-gaps of the two permanent magnets P M. The series coils SE.C. are wound round the poles created by slotting the iron yoke which is fixed above

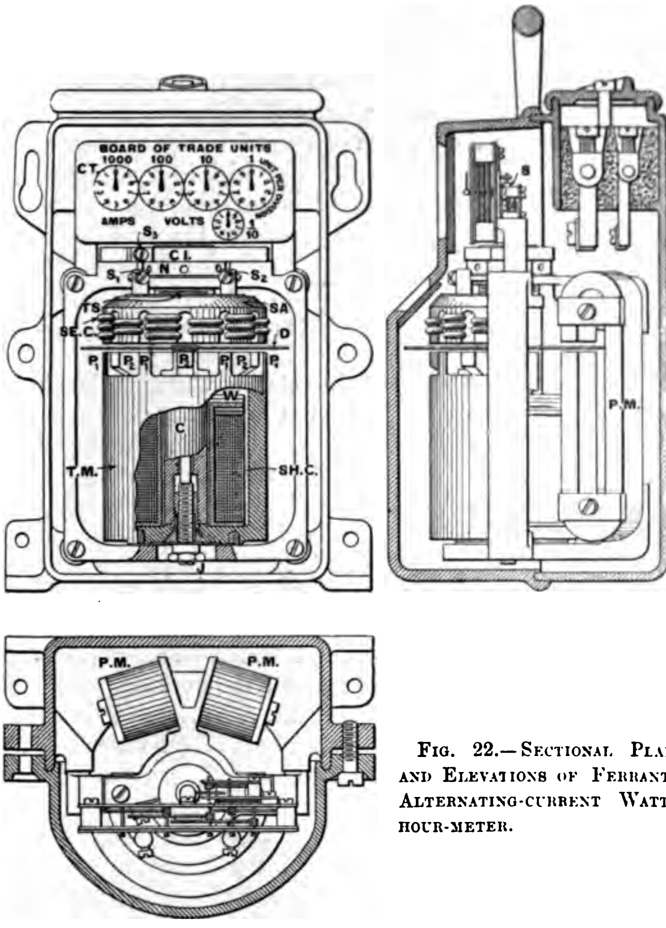


Fig. 22.—Sectional Plan and Elevations of Ferranti Alternating-current Watt-hour-meter.

the disc, a wave form of winding being adopted. The shunt circuit consists of a single coil SH.C wound on a bobbin placed round the core C of a tubular magnet T M. This magnet is provided with four projecting poles P_1, the core having three

poles P_2, and it will be noticed that the latter are almost immediately under the slots of the upper or series magnet. Compensation for friction and adjustment at low loads is effected by turning the series poles about the axis of rotation of the disc. This causes the shunt coils to exert a torque on the disc. If the series pole be turned clock-wise the disc will tend to turn in the opposite direction. The two screws S_1 S_2 butt up against the frame and keep the series magnet in position. By loosening the one and tightening the other it is possible to alter the position of the series magnet where necessary by the desired amount. The high-load adjustment is easily performed by raising or lowering the series magnet, thus altering the air-gap and making the field weaker or stronger. The series magnet has a threaded spindle T S which runs up or down the nut N. When the necessary adjustment is made the spindle is clamped by means of the clamp C L and screw S_3.

The meters may be adjusted to start on about one-hundredth of full load; the torque is, however, rather low (approximately 0·88 gr.-cm. at full load), consequently any additional friction would cause greater errors at low loads than if the torque were larger. The wheel train is well made and the rotor light (18 5 grammes), so that friction ought to remain fairly constant. The speed of meters of all sizes is 40 revs. per min. at full load, which simplifies testing.

The Hookham Induction Motor Meter.—This meter is illustrated in Fig. 23, which shows clearly the working parts. The spindle B carrying the aluminium disc A is driven by the shifting magnetic field set up by the shunt magnet D (on which is wound the shunt coil E) and the two main coils F. Only one of these is seen in the figure, the other being exactly behind it. The shunt magnet D is fitted with adjustable pole-pieces, G, on its upper pole, by means of which irregularities in the curve of the meter may be corrected. The meter illustrated possesses no compensating device for altering the angle between the fluxes, and is intended for use on non-inductive circuits. In using uncompensated meters care should be taken that they are not installed for the purpose of metering energy supplied to enclosed arc lamps or other inductive apparatus.

The brake field is, as usual, produced by a permanent magnet, which is of a somewhat different type to that found in meters of other makes. The lower pole of this magnet is reduced in section just below the pole-piece, with the object of making the "permanence" remain. When testing this meter the case must be kept closed, as, being constructed of iron, it

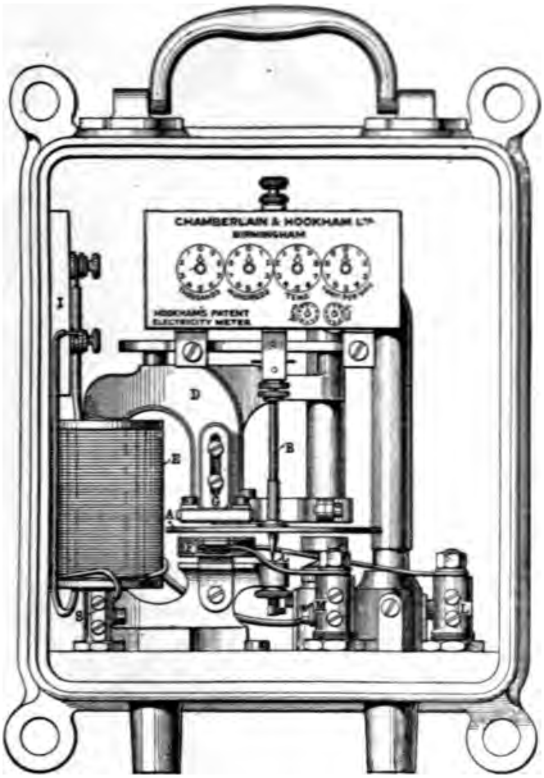


FIG. 23.—HOOKHAM A.C. METER. FRONT REMOVED.

affects the brake. The effect of the door being open has been found to cause a difference of 4 per cent. on a meter of this type (the meter being slow with the door open). The meter is provided with a clamping gear, which can be operated (without opening the main cover) through the opening in the door, the cover of which is taken off when connecting the meter into circuit.

A measurement of the full-load torque of a meter of this make gave the value as 0·845 gr.-cm., the weight of the moving system being 25·2 grammes.

The Hummel Induction Motor Meter is manufactured in Germany for the Electrical Co., and is an example of good

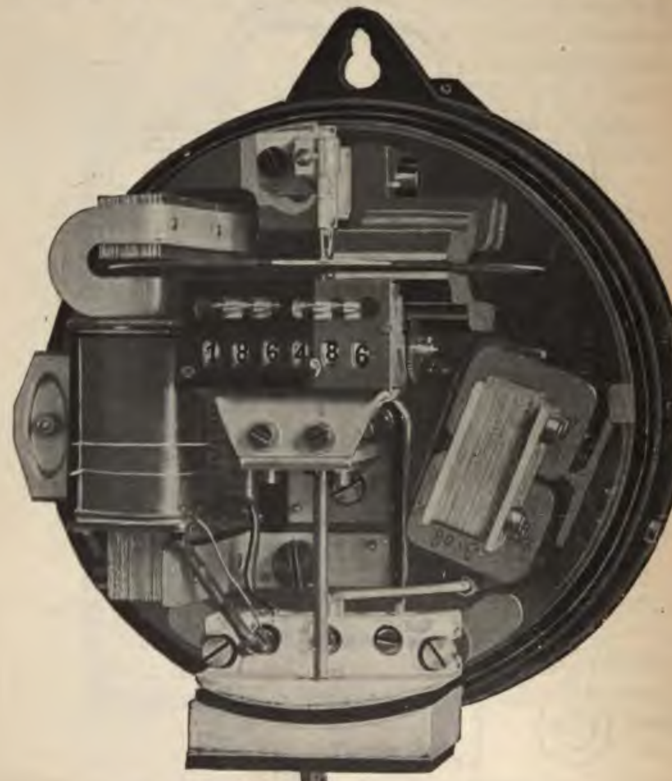


FIG. 24.—HUMMEL METER, WITH COVER OFF.

workmanship, being extremely well made. Fig. 24 illustrates this meter with its cover removed. The motor is on the left and the brake magnet on the right. The meter is fitted with a cyclometer dial train worked by a worm on the main spindle. On the right of the meter is a choking coil,

which is in the shunt circuit. The motor consists of a three pole core (Fig. 25) with a laminated yoke above the disc. The shunt windings are placed on the outer limbs, the series coil being divided between the middle limb and one of the outer ones. The shunt windings produce a torque if their magnetic effects are different, and this is made sufficient to overcome mechanical friction, the meters being slightly over-compensated, which causes them rather to over-register than to under-register at light loads. In order to prevent registration on open circuit when thus compensated, a small piece of iron wire fixed to the disc is attracted by the brake magnet, and is

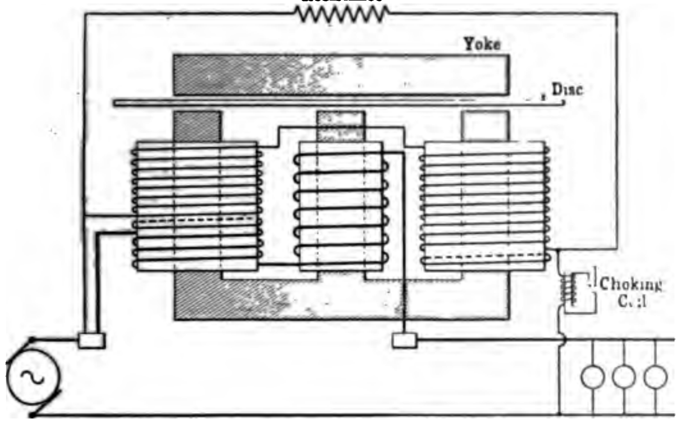


FIG. 25.—HUMMEL METER. DIAGRAM OF MOTOR

just sufficient to pull the armature up when in the position of maximum effect. The turns of the series coil on the outer limb are in the opposite direction to those of the shunt coil on that limb. If only one series coil were employed, the field of that coil would affect the fields of the shunt coils strengthening one and weakening the other. To prevent the strengthened pole becoming saturated, the series winding is put on that limb. The bottom of the main spindle rests on a steel ball, which replaces the pivot, and rotates on a jewel in a bath of watch oil. The jewel mount is held in position by a piece of spring brass, and is removed for inspection with comparative ease. A novel feature in these meters is the top

bearing. Instead of the top of the spindle being turned down to a small diameter and running in the bearing, the spindle is enlarged and carries a small piece of brass, which forms the bearing. A straight piece of steel wire of small diameter, fixed at its upper end, protrudes at the bottom of a tube of much larger diameter than the wire, and passes through the bearing at the top of the spindle. In this way a flexible bearing is formed, and the rim of the tube serves as the top stop of the clamping gear. The full-load torque, which is about 4·8 gr.-cm., is very high, and as the friction is small the meter should remain accurate, provided the cyclometer train does not introduce variable friction. The moving system only weighs 28 grammes, and, considering the high torque obtained with so comparatively light a rotor, the result is very creditable.

This meter has a small full-load drop (about 0·5 volt for a 5-ampere meter) and a shunt current which is about the average. The shunt current of a 200-volt 5-ampere meter is 0·06 ampere, which makes the apparent watts 12·0. The true watts being 1½ per 100 volts—that is 3—the lag of the shunt current is approximately 75 deg.

The Scheeffer Meter.—The Scheeffer meter is an example of Canadian manufacture, being made by the Packard Electric Co. at St. Catherine's, Ontario, the agents being the Bastian Meter Co. The type G meter replaces what is claimed to be the first induction meter on the market, and when the modern meter is compared with its predecessor a good idea is obtained of the progress which has been made in the manufacture of meters. A model G meter of this make with its cover removed is seen in Fig. 26. An iron frame supports the motor, brake magnet, dials and jewel screw, the brake magnet being held by an adjustable clamp on the front, and the motor fixed by screws to the back of the frame. The general arrangement of the motor is seen in Fig. 27. The main coil M is placed between the poles of the shunt magnet S and has no iron core. Below the poles of the magnet is placed the disc with the yoke Y below it. The shunt current is taken first through the choking coil C, which has a nearly closed magnetic circuit, and then round the two poles of the shunt magnet.

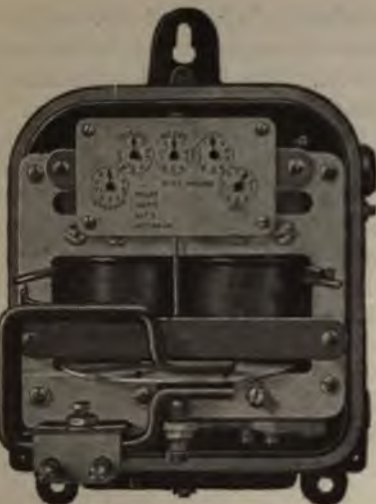


FIG. 26.—SCHEEFFER METER (MODEL G), WITH COVER REMOVED.

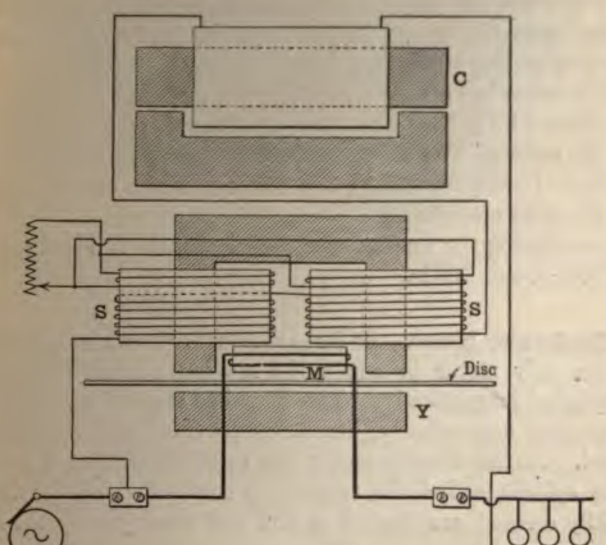


FIG. 27.—SCHEEFFER MOTOR. DIAGRAM OF MOTOR.

The compensation for inductive loads consists of a secondary winding on the shunt magnet, which is regulated by the resistance in its circuit. The low-load adjustment is effected by altering the position of a projecting piece of iron fixed by a screw to the frame below the disc on the right-hand side. Moving this adjusting piece down increases the speed. The meter should be adjusted, on shunt only, until it does not creep in either direction. The disc is of aluminium, and is supported by a light brass tube; the latter rests on a highly-polished and hardened-steel ball, which takes the place of the pivot. The jewel and ball can be inspected or replaced without disturbing the calibration of the meter. The disc and spindle together weigh about 19 grammes. The terminals are in the main case, but the meter may be connected up without breaking the cover seal. The mains are inserted through vulcanised fibre bushes, one at each side of the meter near the bottom, the clamping screws being worked from underneath. A cover capable of being sealed is fixed over the screw heads. The shunt tee is taken to the small terminal on the right-hand side near the top, the fixing screw in this terminal requiring to be sealed by sealing-wax. This is rather a disadvantage, as two kinds of sealing appliances have to be used.

The meter has a very straight curve, and does not appear to be affected by a dead short through a fuse of treble the capacity of the meter. The shunt current is low (0·02 ampere for a 200-volt 10-ampere meter), and the drop is also small (0·1 volt on the same meter).

Considering the smallness of the friction the full-load torque of 1·37 gr.-cm. is fair.

The Stanley Meter.—So far as the Author is aware the Stanley is the only meter in which the moving portion is entirely suspended magnetically. The Evershed meter* was partially suspended magnetically, but it was provided with a pivot and jewel. In the Stanley meter the rotating disc, with its soft steel spindle (called the suspension core) to which the disc is rigidly secured, are floated in air, and consequently the only

* See *Journal* I.E.E., Vol. XXIX., No. 146, p. 743; also *The Electrician*, Vol. XLV., 1900, pp. 283, 328, 438, 513, 562.

mechanical friction is that due to the wheel train, and perhaps the rubbing contact between the bushes in the steel spindle and the taut wire which runs through them.

Fig. 28 illustrates the model G meter with the front part of the case removed, the registering dials, brass frame and brake magnets being visible. The two horse-shoe brake magnets butt up against common pole-pieces, which are held rigidly in the brass frame, the object of this arrangement being to eliminate any chance of the length of the air-gap or distance between the poles taking place. The same arrangement is adopted in the case of the suspension magnet seen in position

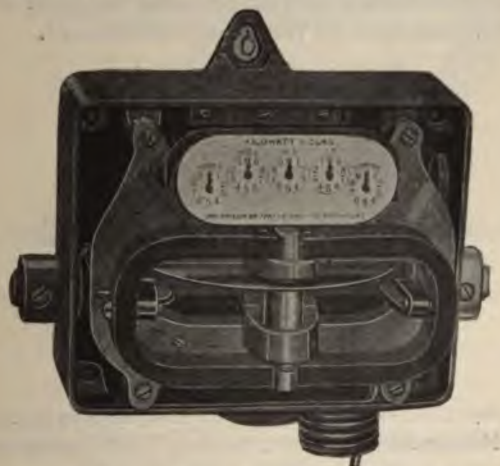


FIG. 28.—STANLEY METER: FRONT VIEW OF SUPPORTING FRAME, SHOWING BRAKE MAGNETS, DIAL, &c.

in Fig. 29, which also shows the dial train connection. A sectional view of the suspension system is given in Fig. 30. It consists of the permanent magnet Y, with its steel pole-pieces, A and B, and the suspension core. The upper end of this core is turned smaller and the lower end is flanged larger than the middle of the core; the pole-pieces are hollow, and the diameters of the hollows are larger than the diameters of the top and bottom of the core. Until the magnet is in position, the core rests on its flange in the cup in

the lower pole-piece; the top of the core will then be just out of the hollow in the upper pole-piece. On placing the magnet in position the core is attracted and raised off the cup, and takes up a definite position between the two poles, touching neither. A fine steel wire is passed through the centre of the core and prevents a shock displacing it. It is stated that this wire does not touch the holes in the core through which it passes. It is a difficult matter to prove this, as the clearance between the wire and these holes is extremely small. Judging by results it seems probable that there is no rubbing contact here; thus the only mechanical friction in the meter is that due to the wheel train, and, owing to the fine finish which this has, the friction must be very small and constant.

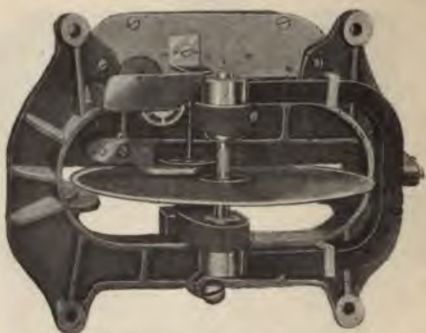


FIG. 29.—BACK VIEW OF SUPPORTING FRAME, SHOWING SUSPENSION MAGNET, ROTATING PARTS, AND DIAL TRAIN CONNECTIONS.

A diagram of the motor is given in Fig. 31, from which it will be seen that there are four shunt coils and two series coils, and that the arrangement is symmetrical as regards the disc, half being above and half below. The series coils contain no iron core, so that the inductive drop is not great (it is about 0·35 volt for a 10-ampere meter). The shunt terminal on the left is to enable the shunt circuit to be disconnected from the main for testing purposes. RR are closed rings of copper forming shading coils, and are placed on the back half of each of the shunt pole-pieces. The vanes shade portions of the pole-pieces also, and by them the meter is stopped if it has any tendency to rotate on no load. These, together with the disc,

cause the necessary lag in the shunt flux for accuracy on inductive load. The permanence of the magnetic suspension is the

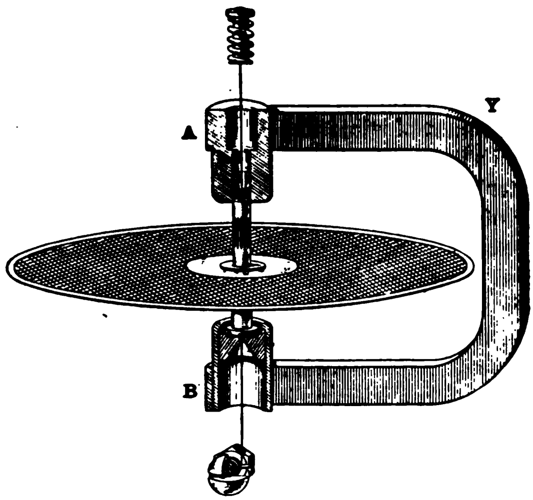


FIG. 30.—MAGNETIC SUSPENSION SYSTEM OF STANLEY METER.

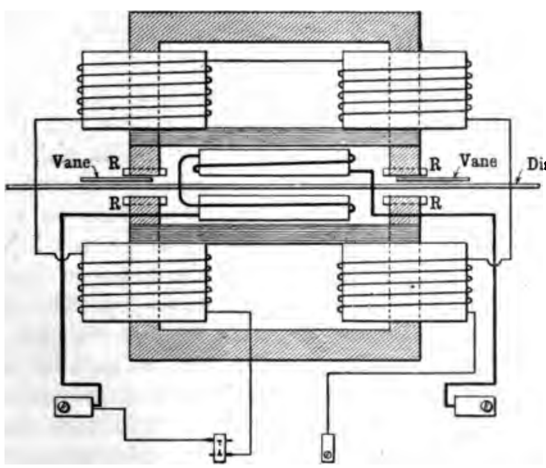


FIG. 31.—STANLEY METER. DIAGRAM OF MOTOR.

only doubtful point in this meter. The Author's experience of the behaviour of this method of suspension of the moving

system only extends to two years, during which time no trouble has been found either in the suspension or otherwise.

The torque necessary to overcome friction practically vanishes, but by means of the vanes (Fig. 31), it is possible to cause a forward or backward creep : thus the friction due to the wheel train may be compensated for. When so compensated even, no amount of vibration causes a creep. The more the right-hand vane, or the less the left-hand one, shades the pole, the greater the torque due to the shunt circuit becomes. The accuracy of the meter extends far below the single 8 c.p. lamp even in meters of large capacity. Notwithstanding the absence of friction, the meter has an extremely large torque for the induction motor type, it being 5·6 gr.-cm. at full load. If, therefore, the magnetic suspension proved a failure—of which there is no indication at present—the meter would be exceptionally good if fitted with a jewel and pivot, for the moving system is not heavy, its weight being 25 grammes, so that pivot friction would not be above the average. The shunt current of 100-volt meters is about 0·08 amp., the shunt watts being about 1·3 ; thus an angle of about 80 deg. is obtained between the shunt current and the impressed volts. The Stanley meter is made in America by the Stanley Instrument Co.

The Thomson Meters.—The Thomson Type K integrating induction watt-hour meter is a neatly-designed instrument of simple construction. Fig. 32 shows this meter with its cast aluminium cover removed. The rotating parts consist of a steel spindle having a polished base which rests on a jewel, the latter being supported by a spring to prevent injury by vibration or any sudden jar. The spindle carries an aluminium cylinder having small ribbed spokes on the top. The cylinder and spokes are all in one piece, the whole forming a strong though light rotor. The motive part, as may be seen in Fig. 33, consists of two hollow main coils placed outside the cylinder, with a shunt magnet placed equidistant from the axes of the main coils. The rotating cylinder passes through the air-gap of this magnet, the main portion of which is inside the cylinder. The iron of the upper limb is in two portions, the shunt bobbin being placed over both. A secondary coil, which is short-circuited through a resistance, is wound on the

upper half of this horizontal limb. This serves as a starting coil; it is fixed independently on a bracket, and can be shifted so as to create a small shifting field in conjunction with the shunt field, and is provided with a screw adjustment (seen at C, Fig. 32). By this means a torque can be produced necessary to overcome the mechanical friction, and thus a high degree of accuracy on light loads can be obtained. This coil also helps to create the 90 deg. lag between the shunt and series fluxes.

On the under portion of this same limb is another secondary winding which is not made use of in meters intended for high

FIG. 32.—TYPE K WATT-HOUR-METER. SIDE VIEW, WITH COVER REMOVED.

FIG. 33.—TYPE K WATTMETER, WITH COVER, ROTATING PARTS AND REGISTERING MECHANISM REMOVED.

frequencies, but by short-circuiting this coil through a resistance provided the meter becomes compensated for a low-frequency supply. The ends of these resistances are brought down to the choking coil, which is seen at D in Fig. 32 behind the permanent magnet support.

By simply unscrewing two screws the dial train and top-bearing bracket can be removed, when the disc and spindle may be lifted out; thus the working parts are easily inspected and can be replaced without affecting the calibration. The meter has a torque which is higher than that of most induction

meters, the full-load torque being about 4·7 gr.-cm. The main moving portion is somewhat heavier than that of several other meters of the same class, its weight being approximately 42 grammes, but the difference in weight is more than compensated for by the increased torque.

The Thomson Type A.C.T. meter is the latest type of integrating induction watt-hour meter brought out by the British Thomson-Houston Co., and is a very small, compact meter. Fig. 34 illustrates the meter which, in sizes up to 50 amperes inclusive, measures 7⅞in. long by 5⅛in. wide by 4⅝in. deep, and weighs 5⅜lb. Its cover beds on to a cotton packing and

FIG. 34.—THOMSON A.C.T. TYPE METER.

is fixed by a single thumb screw. The main moving part consists of the usual main spindle carrying a copper disc. The spindle is supported on a jewel resting on a spring, and no clamping gear is provided. The stationary portion of the motor is of simple design as may be seen in the diagram (Fig. 35). The shunt coils are wound on the upper magnet, which has long pole-pieces, the main coils being wound, one on the pole-pieces of the shunt magnet and the other on the laminated core underneath the horizontal air-gap through which the disc passes.

The compensation for accuracy on inductive loads is effected in this case by producing a resultant main flux by means of the additional main coil and the resistance in series with the main coil of least self-induction, final adjustment being made by altering this resistance. The adjustment on low loads is made by causing a leakage path for the shunt flux through the horizontal air-gap and disc and the thin piece of iron I on the left, the alteration being made by regulating the distance between the bottom end of this piece of iron and the core on which the lower main coil is wound. An iron plate is

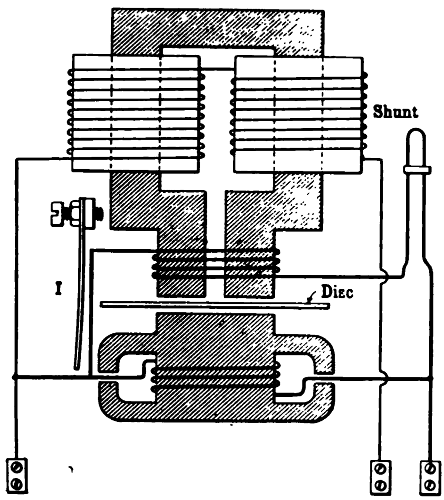


FIG. 35.—THOMSON A.C.T. METER. DIAGRAM OF MOTOR.

placed in front of the motor and shields the permanent brake magnet as seen in Fig. 34. The brake field strength is adjusted by altering the leakage path by means of the screws in the iron plate facing the magnet poles.

This meter has been found to have a very straight line law, with no difference in the constant on a circuit the power-factor of which was 0·5.

The shunt current of these meters is very small—viz., 0·0235 for 100-volt and 0·009 for 200-volt meters. Notwithstanding this, a very fair full-load torque is obtained, it being about 2·4 gr.-cm. This torque, with such small shunt loss, is

due to the employment of a somewhat heavy copper disc, or rotor, which causes the weight of the moving system to be about 62 grammes. Pivot friction is, therefore, relatively high in this meter. The dial plate is of silvered metal, and dial runs can be obtained in short periods by means of the fractional dials, which indicate 0·1, 0·01, and 0·001 units per division on the smaller meters. In order to prevent confusion in reading these dials are blackened. Where any trouble is anticipated, due to meter readers making incorrect readings, the hands on the fractional dials may be removed after testing.

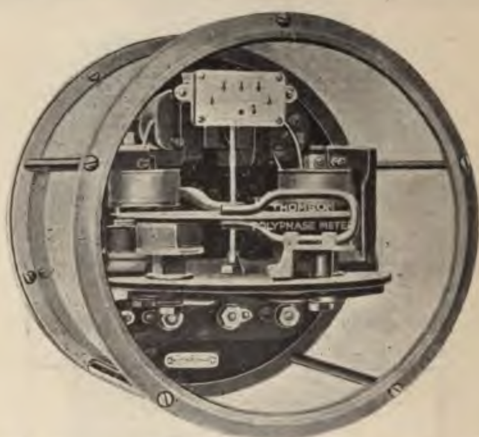


FIG. 36.—THOMSON POLYPHASE METER. SWITCHBOARD TYPE, "ROUND" PATTERN.

For two- and three-phase supply circuits a meter of a special type is made by the British Thomson-Houston Co., as illustrated in Fig. 36. It is stated to be suitable for either balanced or unbalanced loads, and consists of two motors acting on a common disc-armature, which also serves as the brake disc, being retarded by two permanent magnets of the usual Thomson type. Fig. 36 is a view of the switchboard type of this meter; it is also made in a rectangular pattern, with zinc cover and front connections. For circuits in excess of 150 amperes and 650 volts current and potential transformers are used.

The Westinghouse Integrating Wattmeter is another example of the induction motor meter. It is the outcome of the Shallenberger, which was of much heavier design and probably the heaviest electricity meter made, although the moving portion was light. The Westinghouse meter is much lighter and smaller than the Shallenberger meter, being a very compact instrument. Fig. 37 is a view of the meter with its cover removed, and shows the permanent magnet which supplies the brake field. The disc is of aluminium, and the steel spindle engages with the first wheel of the train by means

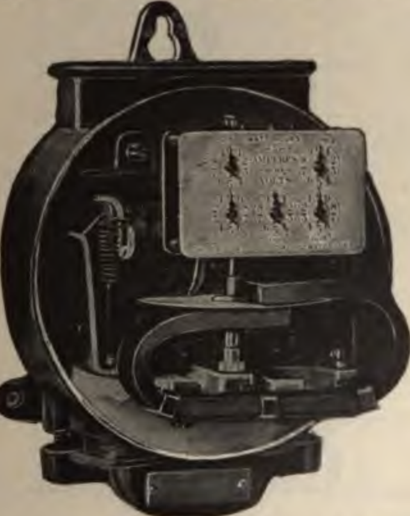


FIG. 37.—SINGLE-PHASE WESTINGHOUSE INTEGRATING WATTMETER, WITH COVER REMOVED.

of a pinion, the worm being introduced higher up in the train. The terminal box is at the top; the mains entering from behind are fixed in the terminals by vertical screws, the heads of which are below the terminal box cover. This arrangement of the mains entering from behind the meter is rather awkward, particularly for making connection when testing *in situ*, as the meter has to be taken off the backing board to insert the standard instrument in circuit. The Westinghouse Company have recently altered the design of this portion, which will be a great improvement.

A better view of the motor is that in Fig. 38, in which the dial train and permanent magnet are removed. The two shunt coils are placed above the disc on a core, which is a closed iron circuit with the exception of a gap (hidden by the spindle) in the centre between the two upper poles, and the air-gap between the upper and lower poles in which the disc passes. Underneath the disc, immediately below the two upper poles, is the other pole, which carries the series or main coil. The shifting of the flux in this meter has already been described. A choking coil, fitted in the base of the meter, is connected in

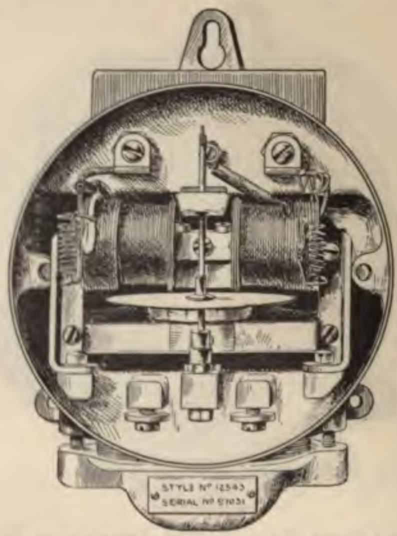


FIG. 38.—SINGLE-PHASE WESTINGHOUSE INTEGRATING WATTMETER, WITH COUNTING TRAIN AND PERMANENT MAGNET REMOVED.

the shunt circuit. The compensation for inductive loads is obtained by the secondary windings on the shunt magnets, which are short-circuited through short lengths of wire by which the final adjustments are made. Compensation for friction and adjustment at low load can be effected by obtaining a small shifting flux due to the shunt fields by adjustment of these resistances so that the secondaries are slightly unbalanced.

A uniform speed has been chosen of 50 revs. per min. at full load for all sizes. In three-wire meters a second series coil is

introduced, one series coil being connected in circuit with each outer. The meters are also made for registering the energy on two and three-phase circuits. These meters contain two motors, the rotors being fixed to the same shaft.

The full-load torque is rather low; from a test on a 100-volt 20-ampere meter it was found to be just over 1 gr.-cm. The shunt current of the same meter was 0·08 amperes, and, assuming the lag in the shunt circuit to be 80 deg., the true

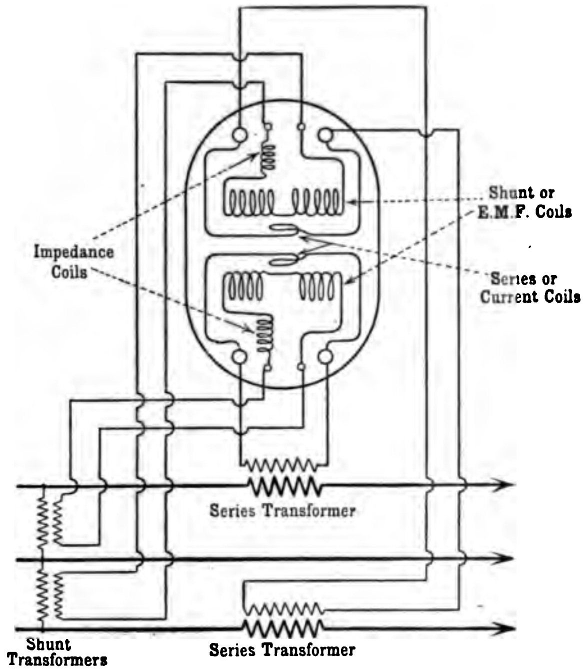


FIG. 39.—DIAGRAM OF WESTINGHOUSE POLYPHASE INDUCTION METER, SHOWING CONNECTIONS WHEN USED WITH SERIES AND POTENTIAL TRANSFORMERS.

shunt watts would be 1·4. The watts lost in the main coil are small, and do not exceed 5 watts in the 5-ampere meter. The moving system is very light, weighing only 16 grammes.

The connections of a polyphase meter of this make are seen in Fig. 39, where the meter is connected in a three-phase circuit by means of series and shunt transformers, as would be

the case on high-pressure circuits. The meter is thus insulated from the high-pressure mains. For low-pressure circuits the transformers may be dispensed with and the meter connected direct into the circuit. For a two-phase circuit the connections are very similar, the top connections being connected in one phase and the bottom ones in the other phase.

Fig. 40 illustrates a single-phase Westinghouse meter of the latest type, with its cover removed. This view shows the

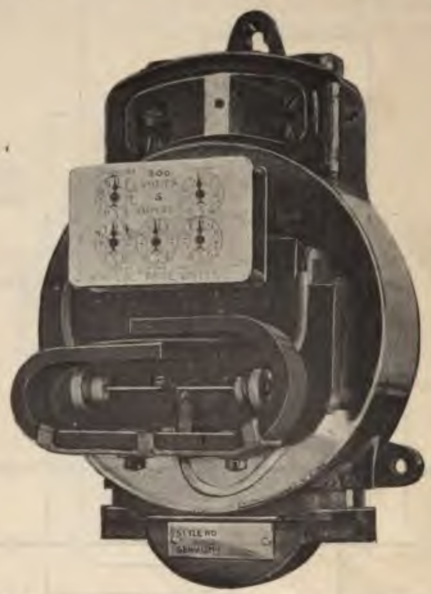


FIG. 40.—WESTINGHOUSE METER. LATEST TYPE. COVERS REMOVED.

improved design of terminal box, in which the mains are inserted through holes in the top, the heads of the clamping screws facing towards the front.

Two other improvements have been introduced into this meter, the first being a shield for screening the brake magnet from the stray fields of the motor, more particularly the intense field which may be generated on a bad short-circuit. This screen consists of an iron shield with a long, narrow slot in it to allow the disc to pass through it freely. It is fixed as

shown, between the coils and the permanent magnet, covering the whole of the stationary portion of the motor.

The second improvement is the introduction of a simple low-load or starting adjustment, consisting of a rod held by insulators, and having a sliding terminal which is capable of being moved up or down the rod and clamped in any desired position. This, as seen in Fig. 40, is placed in the centre of the brake magnet in front of the screen.

Moving the terminal along the rod to the right increases the friction compensating torque, and a point is reached when the disc just turns when on open circuit if the friction is normal. The sliding terminal should be clamped in the position where the disc just stops.

CHAPTER III.

CONTINUOUS-CURRENT METERS.

It will be noticed that all the alternating-current meters which have been described have been watt-hour meters, whether they be for the measurement of energy supplied to inductive or to non-inductive circuits, and, so far as the Author is aware, there have been but few examples of alternating-current ampere-hour meters—among which may be mentioned the Ferranti, Ferranti-Wright, and Schallenberger—which have seen any extensive service. With continuous-current meters, however, it is different: the great majority of those meters which are suitable for continuous-current circuits *only*, are ampere-hour meters. There is, moreover, a greater difference between the meters of different makes, some depending on electrolysis and differing among themselves considerably, whilst those of the motor type may be divided into two classes —*i.e.*, the mercury motor class, and the commutator class. The permanent magnet plays even a greater part in the continuous-current motor meters than in those suitable exclusively for alternating-current, for in a great many instances it becomes an important member of the motor as well as of the brake.

The Acme Continuous-current Meter is a watt-hour meter of the motor type, possessing some novel features of construction. Fig. 41 illustrates the meter with its cover removed. The mechanism is mounted on a zinc base on which a cover of insulating material fits tightly. The main spindle carries an armature composed of an astatically-arranged iron core, magnetised by a stationary shunt coil. By employing such an armature it is claimed that a large torque is obtained with almost complete independence of external magnetic fields, and also that the hyteresis errors are so small as to be practically inappreciable. By using an iron armature no commutator is

required on the main spindle, but a contact device for changing the direction of the current in the shunt coil (to reverse the polarity of the iron armature twice in each revolution) is mounted on a separate spindle. Sparking is reduced to a minimum by the introduction of a non-inductive resistance (in circuit with which is a small electro-magnet) in parallel with the

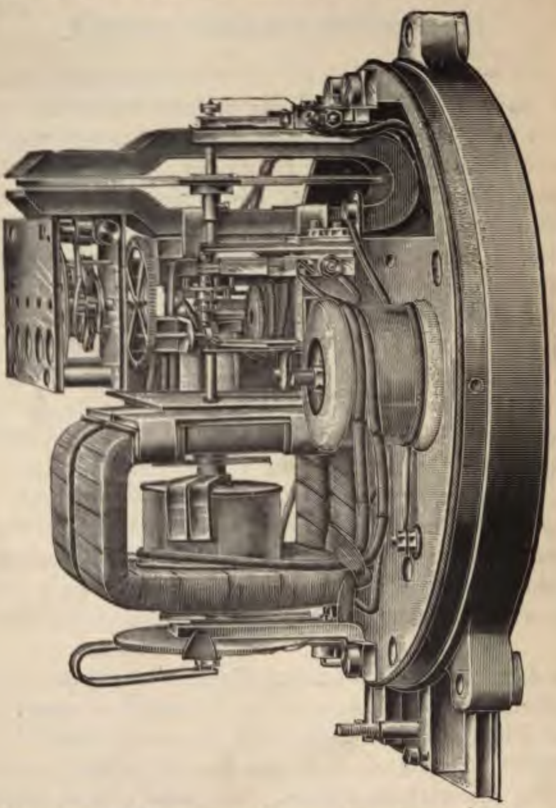


FIG 41.—ACME C.C. WATT-HOUR METER. SIDE VIEW WITH COVER OFF.

armature coil, this auxiliary resistance being short-circuited except during the period of commutation. The point of reversal of the armature is a dead point, but a torque sufficient to carry the rotating part over this dead point is obtained by means of the electro-magnet referred to above acting on an

auxiliary armature during the period of reversal. Acceleration above the desired speed is prevented by the usual magnetic brake.

Referring to Fig. 42, which is a diagrammatic view of the meter, the main spindle 3 carries the iron armature 6, whose pole-pieces 7 and 8 rotate respectively outside and inside the main coils 10, 11. The current in the shunt coil 9, which

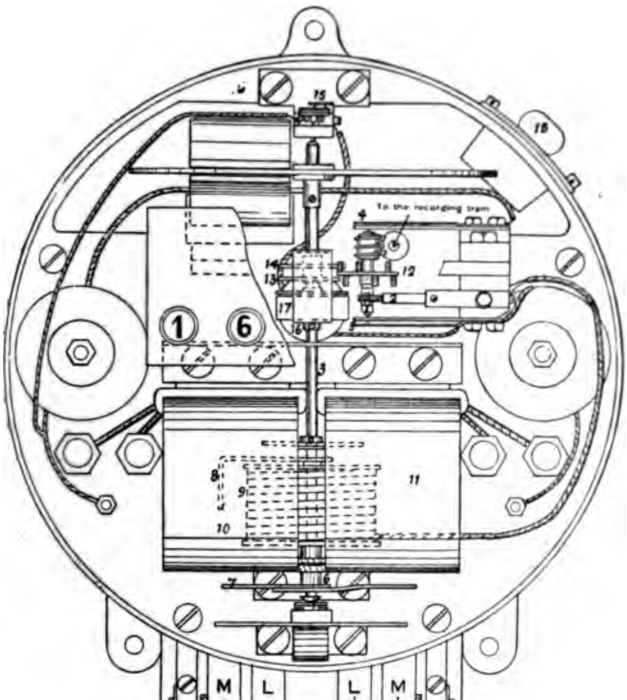


FIG. 42.—ACME C.C. WATT-HOUR METER. FRONT ELEVATION.

excites the armature, is reversed twice in each revolution by the commutator. The brushes 2 are connected with the stationary armature coil and the current is led to the segments by the contact blades 4 and 5, which bear on the ends of the commutator spindle. On the same spindle a disc is mounted having a number of pins round its periphery corresponding to

the number of commutator segments. Opposite these pins two semi-circular discs, 13, 14, are mounted on the main spindle in such a position that they engage with the pins and turn the commutator the distance of one segment per half-revolution of the main spindle. The electro-magnet 16 acts on the auxiliary armature 17, and thus causes the torque, which carries the main spindle over the dead point. This electro-magnet is brought into action by the contact device 15 fixed on the top end of the main spindle. The additional impulse comes into operation during about $\frac{1}{16}$th of a revolution, so that the contact friction due to the commutator is reduced to about one-eighth that in meters whose brushes are constantly in contact. Further, as during the change from segment to segment an additional torque is produced, the friction caused by the changing has not to be overcome by the driving torque. A worm on the commutator spindle drives the recording mechanism.

The shunt loss is stated to be about two watts, whilst the pressure drop at full load varies from 1·2 volts in the three-ampere meter to 0·8 volt in a meter of 50-amperes capacity. The Author has not had an opportunity of testing this meter, which, in order to do away with the simple commutator, common to most continuous-current watt-hour meters, is rendered somewhat complicated.

The Bastian Meter.—The Bastian meter is an electrolytic meter, and perhaps the simplest in construction of any. It is, in reality, a voltameter, through which the whole current to be metered passes decomposing water into its two component gases, which are allowed to escape. The drop in level of the remaining electrolyte is taken as a measure of the ampere-hours (or Board of Trade units at a declared pressure) supplied to the consumer. In the older type, two platinum electrodes are suspended by the conducting leads in the bulb at the bottom of a long glass tube, the top of which is open. The bore of this tube is made as even as possible throughout its length, and the leads are enclosed in two vulcanite tubes screwed into a square vulcanite framing, which forms a mechanical protection to the platinum electrodes enclosed by it. A scale, graduated in Board of Trade units at a definite voltage, is fixed in front of the tube in such a manner that the level

of the electrolyte can be easily read. The glass vessel is fastened in a cast-iron or tinned sheet case, having a door in front, in which is a long window enabling the height of the column of liquid to be seen from the outside. The leads from the electrodes are connected to terminals at either side of the case. The electrolyte is a dilute solution of sulphuric acid and water (a quantity equal to about 6 drachms of water is sufficient sulphuric acid for 5 and 10-ampere meters). As only the water is decomposed, it is only necessary to refill the tube with water. In order to prevent evaporation, which would naturally cause an error, paraffin oil is poured on the top of the electrolyte.

One of the chief objections to this meter is its large pressure drop, which is always more than 1·5 volts, due to the back E.M.F. An additional drop due to the resistance of the electrolyte brings the total drop up to 3 volts at full load on a 5-ampere meter. The drop is variable and depends slightly on the volume of liquid remaining, the maximum drop being at the zero (or top) end of the scale. Another objection is that the tube requires refilling periodically with water, the period depending on the consumption, which may vary considerably in different houses. If left too long all record of the consumption is lost. Each time the meter is refilled the record is lost and may lead to dispute between the consumer and supplier. The scale is held in position by screws passing through slotted holes, so that on refilling the final adjustment of the zero mark to the level of the liquid can be made by altering the height of the scale. The reading should be taken from the top of the water and not from the top of the oil. The calibration of the scale is conveniently checked by filling the tube up to the bottom mark (or maximum reading) with water; then, by means of a burette calibrated in cubic centimetres, pour in quantities of water corresponding to those which would be decomposed by a definite number of units at the voltage on which the meter is to record Board of Trade units. The following table gives the quantity of water decomposed by 10 Board of Trade units at different voltages:—

Cubic cm. of water.	Voltage.	Cubic cm. of water.	Voltage.
34·64	100	15·76	220
31·5	110	15·1	230
23·1	150	14·4	240
17·3	200	13·85	250

The type "N" meter of this make is very similar in design to that just described. The electrodes, however, instead of being of platinum, are of nickel, and they are immersed in an alkaline electrolyte which, it is claimed, has no action on the electrodes. The substitution of nickel for platinum enables

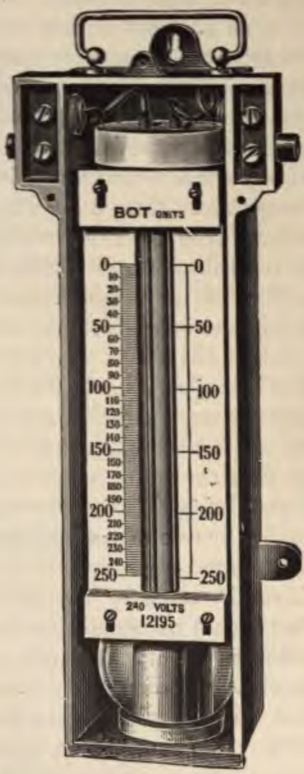


FIG. 43.—BASTIAN "N" TYPE ELECTROLYTIC AMPERE-HOUR METER. COVER REMOVED.

the electrodes to be much larger at a reasonable cost, and, consequently, the drop due to resistance is reduced. The Author has not had much experience with these meters, but has noticed that on the decomposition of the liquid the tube is left coated with a dirty deposit.

Fig. 43 illustrates an "N" type meter, in which, it may be mentioned, the terminals have also been improved. The leads are now pushed through bushed holes in the case to brass binding posts, sulphured in the two compartments, one on each side of the meter. In this way all danger of ignition of the gases given off by a small spark in the terminal is avoided.

This meter is open to the same objections as the former as regards loss of reading and refilling, but against this may be balanced its extreme simplicity, its straight line law, and the small chance of its getting out of order, provided that it is properly attended to—that is to say, regularly refilled before the reading is lost. Its accuracy depends on the accuracy with which the scale is calibrated, together with that with which the last reading before refilling is taken, and on the setting to zero correctly. The reading becomes difficult if the meter is bubbling much at the time of refilling, in which case it almost becomes necessary to have the lights off.

The Eclipse Type C.R. Meter.—This ampere-hour meter is made in sizes up to 10 amperes. It is a motor meter having an armature which rotates in a magnetic field due to two permanent magnets. The armature coils are quite flat, being supported on a partially cut away aluminium disc which forms the brake. The current to be metered is passed through a platinoid shunt having a drop of about 1 volt at full load. A small fraction of the main current passes, by means of very light brushes and a very small commutator, through the armature, which is connected across the shunt, and therefore has a very small voltage applied to the brushes. A light spindle, having its base polished to a hemisphere, rests on a jewel and supports the disc on which the armature coils are laid. Its revolutions are transmitted by a worm on its upper end to a wheel train of the cyclometer pattern. This meter, as in the case of the alternating meters of the same make, is now made with ordinary clock dial trains, which are, in the Author's opinion, far more reliable, their friction being so much more uniform.

In Fig. 44, which is a view of the "C.R." meter, the right-hand magnet has been removed to give a better view of the armature, brush brackets and low resistance, which carries the

main current. The magnets, jewel screw and brush brackets are all supported by a plate standing out from the back. The low-resistance shunt consists of two spirals, seen in the back, one end of each being connected to each main terminal, whilst the other ends are supported by an insulating clamp fixed underneath the magnet-supporting plate near the front. Contact between the two spirals is made through an adjustable clamp; by altering the position of this up and down the straight portions of the resistance (just underneath the supporting plate), a certain amount of alteration in the speed of the meter can be made. The magnets are also adjustable.

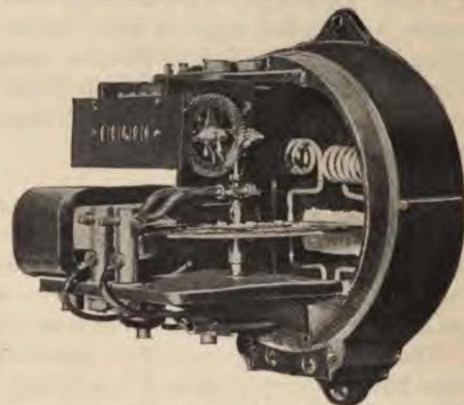


FIG. 44.—VIEW OF ECLIPSE TYPE C.R. METER. RIGHT-HAND MAGNET REMOVED.

A better view of the armature is seen in Fig. 45, which shows how the three flat, fine wire coils are laid on the partially cut-away aluminium disc and held in position by threads at intervals. The three-part commutator, to which the ends of the coils are attached, is just above the disc. The diameter of the disc is $3\frac{3}{4}$in. and the thickness of the disc and coils 50 mils. The diameter of the commutator is 0·11 in., and the weight of the whole moving system 24 grammes. From tests made, the mean torque at full load appears to be about 4·8 gramme-cm. In common with other ampere-hour meters having shunted armatures, the speed is high, being 9,000 revs. per Board of Trade unit, or 300 revs. per min. at full load. Each brush

consists of two extremely thin strips of silver, clamped at one end to the stout brass supporting rod (Fig. 44), the other ends of the strips being held by a fine steel wire which is clamped to the same rod by the second clamp. By this means the strips are caused to bear on a small arc of the commutator. Good contact is obtained in this manner, but at the expense of slightly increased friction. The meter is a very small one, the diameter of the back casting being only 4¾in., which would be advantageous in cramped situations.

FIG. 45.—ARMATURE AND BRAKE DISC OF ECLIPSE TYPE C.R. METER.

The Electrical Co.'s Continuous-current Meters.—This company's type R.A. meter is an ampere-hour meter, and consists of a motor the field of which is supplied by a large permanent magnet. A three-coil armature is connected by its commutator and very light brushes to the terminals of a strip or wire, and thus a small fraction of the main current passes through the armature, the greater part going through the strip, the ends of which are connected to the main terminals. The armature coils are former wound, and are laid on the outside of an aluminium cylinder. The cylinder, passing through the field of the magnet, acts as a Foucault brake. The drop in the main strip or wire is directly proportional to the current passing, and thus the P.D. at the armature terminals is proportional to the main current.

Fig. 46 illustrates this meter with its cover removed. The magnet, as will be seen, is of the horse-shoe pattern, having large pole-pieces bored out to take the armature. In order to make the air-gap as small as possible, an iron core is fixed in

the gap, so that the latter is reduced considerably, and only a small clearance is left between the core and the pole-pieces to allow the cylinder to rotate freely. A hole in the centre of this core allows the spindle to pass down to the footstep. The pole-pieces form a support for the brush bracket and top bearing, and a worm near the lower end of the spindle works the counting train, which is of the cyclometer pattern, as on all the meters of this make.

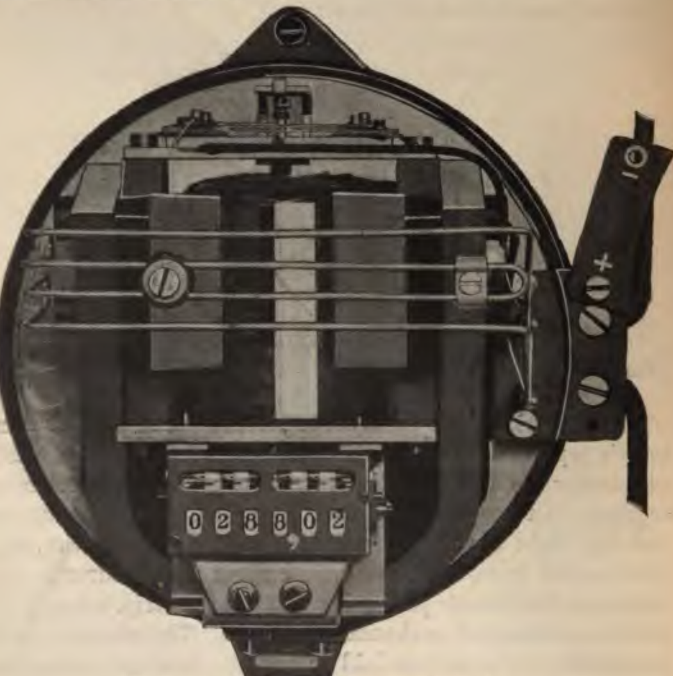


FIG. 46.—THE ELECTRICAL CO.'S R.A. METER.

The speed is adjusted by altering the resistance of the wire forming the main circuit by shifting the position of the clamp, consequently altering the pressure across the armature. There is no compensation for mechanical friction, which is kept as low as possible. The weight of the armature and spindle is 113 grammes. The speed is high (200 revs. per min. at full load), and the full-load torque is also large (16 gramme-cm.);

thus mechanical friction does not affect the curve except at extremely low loads. The starting current is therefore very small, and the meters will start on $\frac{1}{100}$th of full load. The full-load drop is high; the makers give it as 1 volt for all sizes. It depends upon the adjustment to a certain extent, however, and has been found to be as much as 1·4 volt on a 5-ampere meter. The bottom bearing is a jewel, the spindle resting on a ball as described in connection with the alternating-current meter of the same make. A clamping gear is provided to prevent damage during transport, and is worked with a screwdriver through a hole in the case.

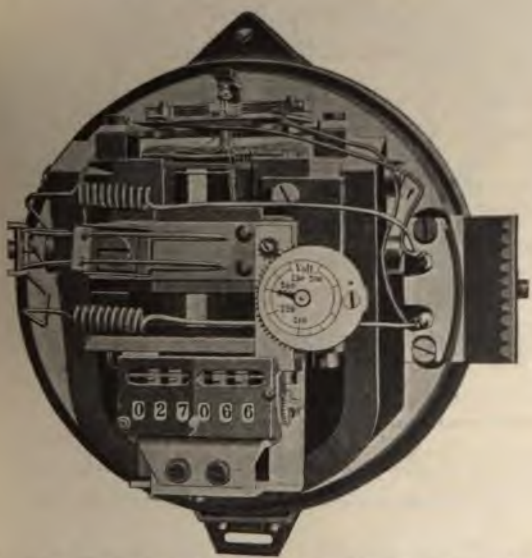


FIG. 47.—THE ELECTRICAL COMPANY'S R.A. METER, WITH ADJUSTMENT FOR VARYING VOLTAGES.

The meters are made up to a capacity of 50 amperes. The watt loss at full load on a 50-ampere meter is 50 watts, a very high figure, being 1 per cent. of the transmitted power on a 100-volt supply.

This meter is also made as shown in Fig. 47 with an adjustment enabling it to read Board of Trade units at varying voltages. Two ranges are provided—viz., 100 to 125 volts

and 200 to 250 volts. The adjustment is easily made by inserting a screwdriver through a hole in the cover just in front of the slot on the pinion (*see* Fig. 47). This pinion is turned until the pointer on the circular dial points to the desired voltage. The hole in the case is then closed by means of a small brass cap, which can be sealed.

The K.G. type meter of the same make is of the oscillating type, and is finished in the usual good style. It is a watt-hour meter, and consists of a fixed main coil (H, Fig. 48), in front

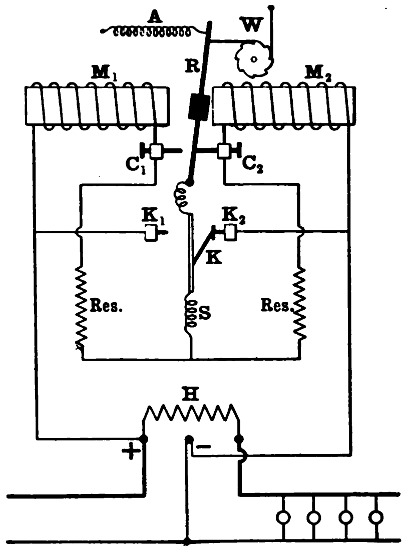


Fig. 48.—Diagram of the Electrical Company's K.G. Meter.

of which a vertical spindle, carrying a small shunt coil, S, and an arm, K, is capable of oscillating, the distance being made definite by the arm K swinging against the two contact stops K_1, K_2.

The shunt circuit is somewhat complicated, and comprises two parts; the one is the shunt coil, and the other a relay which reverses the current in the shunt coil and works the counting mechanism. In Fig. 48, M_1, M_2 are the relay magnets which attract the relay armature R; this armature is alternately pulled towards M_1 and M_2, making electrical contact

respectively with the contact pins C_1, C_2. By means of a ratchet gear, R also works the toothed wheel W, which is the first wheel of the counting gear. The contact arm K alternately strikes the contact pins K_1, K_2, and in doing so short-circuits M_1 or M_2. When M_1 is short-circuited, M_2 pulls R over, and, owing to it being so much nearer M_2, it remains over until M_2 is short-circuited, when it returns to M_1. Thus each time K touches K_1 or K_2 the direction of the current in S is reversed by R making contact at C_2 or C_1. It will be noticed that the shunt current is never actually broken, as the contact points only short-circuit parts of the circuit; the

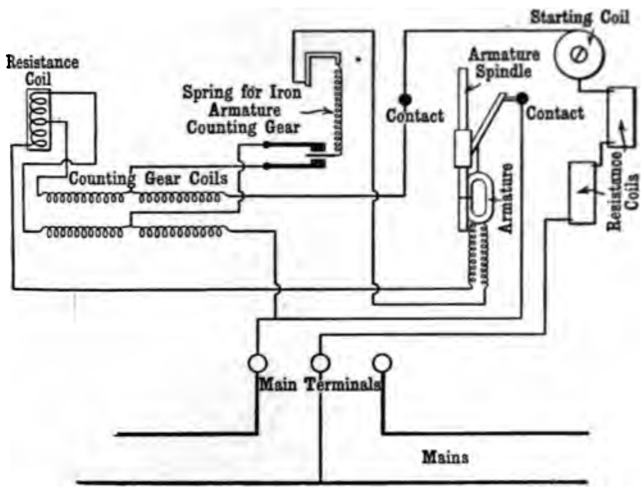


FIG. 49.—CONNECTIONS OF THE ELECTRICAL COMPANY'S K.G. METER.

changes are thus effected without sparking, and, consequently, the contacts should remain in good condition for a considerable time.

The actual connections, as arranged in the meter, are shown in Fig. 49. The meter is provided with the usual Foucault brake, as seen at the top in Fig. 50. The magnet is not movable, so that adjustment at high load must be made by altering the length of path of the oscillating member, the speed being increased by shortening the path. For this purpose the contact pins are screwed.

A compounding coil is provided, being supported on a slotted brass strip, seen to the right in Fig. 50. The counting train, which is of the cyclometer pattern common to other meters of this make, is in this case not worked by the main moving part; consequently any irregularity in its friction will not affect the accuracy—except by jamming and thus preventing the action of the relay, in which case the meter would stop altogether.

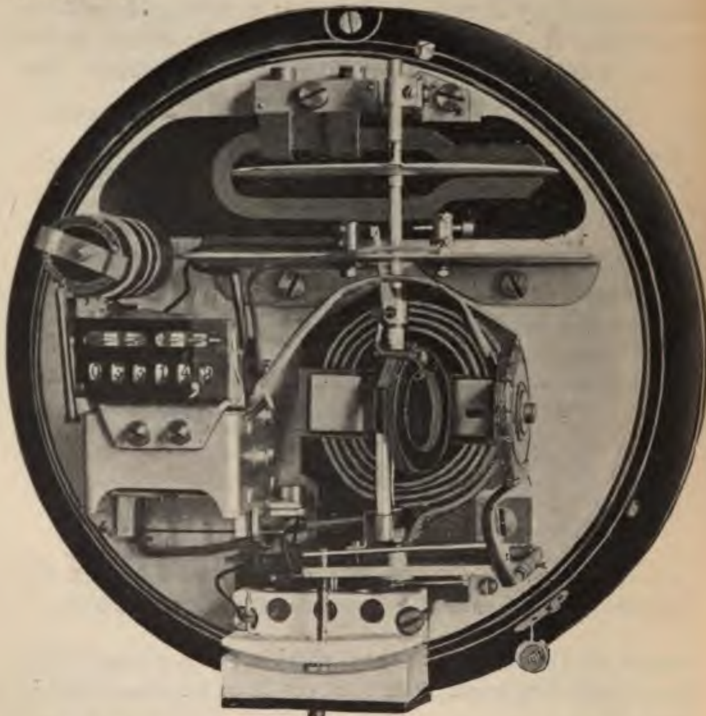


FIG. 50.—INTERIOR OF THE ELECTRICAL COMPANY'S K.G. METER.

The speed of these meters is low (about 80 single oscillations in 100 seconds at full load), the travel of the contact arm being only through a small angle. The moving portion, therefore, should be very accurately balanced and the meter installed plumb, otherwise the oscillation in one direction would take a

much longer time than in the other, making the meter slow at low loads and increasing the starting current.

The object of the oscillating meter is to provide a continuous-current watt-hour meter not having a commutator or other rubbing parts, and so reducing the friction. The current is carried to the moving coil by two very small spirals of fine

FIG. 51.—THE ELECTRICAL COMPANY'S S TYPE METER.

wire. The length of these wires is great, so that their torsional effect is negligible. The angle through which the moving coil oscillates being small, no practical difference is discernible in the torque, which is very low. The full-load torque of a 200-volt 10-ampere meter of this type was found to be just under 1 gramme-cm. The only friction is the top and bottom bearing

friction, but a damaged jewel would, owing to the lowness of the torque, have a large effect on the accuracy of the meter.

The Electrical Co.'s "S." type meter is a modification of the K.G. meter just described, and is intended for switchboard and heavy power circuits. Fig. 51 illustrates the switchboard type, from which it will be seen that the meter is astatic. The main and moving coils are doubled, so as to be unaffected by stray fields. A particular advantage possessed by this meter is that its registering gear is not contained in the meter case proper, the relay and dials being enclosed in a small case, the two portions requiring only to be electrically connected by the five small wires. These are supplied with the meters in the shape of a flexible cable; thus it is possible to have the recording gear on the switchboard, where it takes up very little room (the case being about 8½in. in diameter), while the meter proper is erected at any convenient point up to 100ft. or 200ft. away. This type is made in sizes of from 300 amperes to 1,500 amperes for various pressures.

The Ferranti Continuous-current Meter.—This meter, which was first brought out several years ago, has been improved from time to time, and in its present form is seen in section in Fig. 52. Its action depends on the principle that if a mass of mercury has a current passed through it from its centre to its circumference, or in the reverse direction, and is in the field of a magnet, so that the lines of force are at right angles to the direction of the current, the mercury will revolve at a speed proportional to the current and to the field. Thus, if the same current which flows through the mercury excites the field, the speed may be proportional to the square of the current. The fluid friction of the mercury against the sides of the vessel which contains it increasing nearly as the square of the velocity, the resultant speed is practically proportional to the current. The meter is really a small series motor consuming a very little power. In Fig. 52 T + and T − are respectively the positive and negative terminals. From T + the current passes up through the steel pole SP and into the mercury bath MB at its centre, C, through the mercury to the circumference, where it leaves by the circular iron ring IR to enter the coil CC, leaving by the negative terminal T −. The magnetic

circuit is closed, except at the gap, which forms the mercury bath. The iron at the top and bottom of the gap is insulated by vulcanised fibre. A very light fan, F, having four blades immersed in the mercury, transmits the motion of the mercury by means of the worm W on its spindle to the wheel train. As the speed of the mercury cannot be

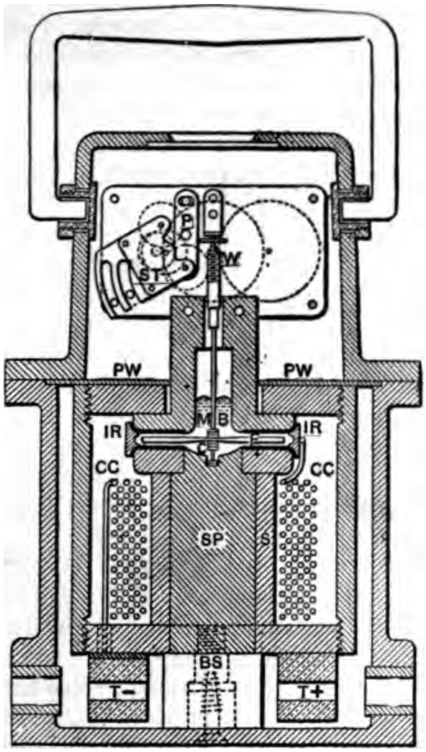


FIG. 52.—SECTION OF FERRANTI METER.

predetermined, in order to make the meter direct-reading in Board of Trade units the train is divided into two portions—the fixed portion and the adjustable portion, the latter (called the swing train, ST) being fixed on the back of the former. The swing train has two adjustments. One allows the worm and worm-wheel to be brought into exact gear, which is effected

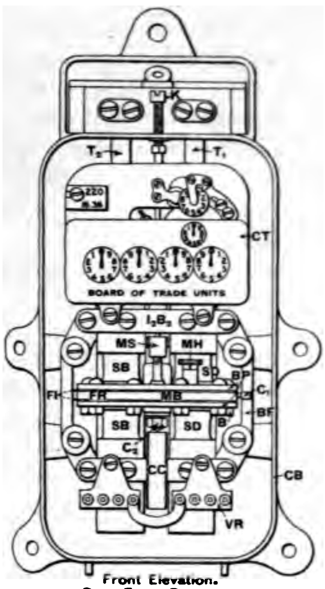
by means of the swing plate P. The second adjustment allows the swing train to be turned round the centre of its first wheel to permit of pinions and wheels of different ratios being inserted, in order that the front dial hands may read Board of Trade units without having to be multiplied by a constant. A substantial cast-iron case encloses the meter, the live portion being insulated from the case by a pressphan washer, PW, on the top, and by an insulating block between it and the bottom of the case. In the older type meters a rush of current, such as would occur on a short-circuit, over-magnetised the steel pole, thus causing the meter to over-register for some time afterwards. To avoid this a soft iron sleeve, S, has been put over the steel pole, forming a shorter return path than through the mercury bath.

After short-circuiting a 5-ampere meter through a 20-ampere fuse on a 100-volt supply, the Author has found a difference in the constant of 0·4 per cent., showing that no appreciable alteration is caused by an abnormal short-circuit. A certain amount of residual magnetism left in the steel pole enables the meter to start on very low currents, and causes the meter to read rather higher on descending than on ascending loads.

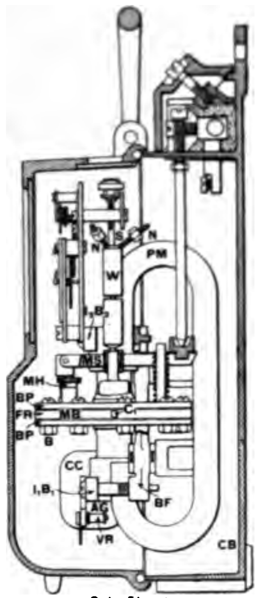
The spindle with its fan is extremely light, probably the lightest main moving part of any meter; moreover, it tends to float partially in the mercury, thus wear of the jewel must be practically nil.

The full-load torque of a 5 ampere 100-volt meter was found to be about 2 gramme-cm. and the full-load drop 1·5 volts. It seems a pity that no means is provided for closing the chamber containing the mercury during transport, as this would avoid the necessity of carrying the meter upright, to encourage which a handle is provided. One can never be sure that the meter is kept in an upright position on its journey from the test room to the consumer's premises, and upon this depends its accuracy. Another objection might be made to the variable speeds of different meters, which renders tests in situ rather more complicated, as does the fact that the quick moving parts are at the back of the meter. The numbers on the lable attached to the top corner (at the back) of each train are the voltage for which the meter has been calibrated and the ratio of the change wheel and pinion.

The New Type Ferranti Continuous-current Meter.—The new meter (1905) which has just been brought out by Messrs. Ferranti is another addition to the mercury-motor type of



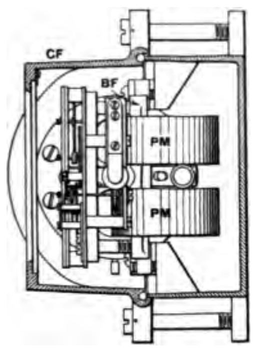
Front Elevation.
Case Front Removed.



Side Elevation.
Case in Section.

Fig. 53.—New Type Ferranti Continuous-current Meter.

meters. It differs from the older meter just described considerably, the main current being passed through an armature instead of through the mercury only, and this armature cuts the fields of permanent magnets. Fig. 53 shows the front elevation with cover removed, side elevation and plan, the case being in section in these two views. By reference to this figure it will be seen that the design is a great improvement on the other type in several ways. The terminal box is at the



Plan.
Case in Section.

top, the terminal screws coming out towards the front, the screw heads being easy of access. One of the greatest improvements is the mercury chamber sealing gear, which is worked by simply turning the screw K in the terminal box. This screw, if turned in a clockwise direction, closes up the mercury chamber, and the meter may then be carried about without fear of the mercury being spilled. The connections are seen in Fig. 54 in which the mercury bath MB is shown in section. The bath is formed by the two nickel-plated brass plates BP—which are insulated from the mercury by fibre insulators, FI—and the fibre ring FR. The plates with the fibre ring between them are bolted together by nine brass bolts, B, which are also nickel-plated. The mercury is poured into the chamber through a hole in MH (Fig. 53), this hole being closed by the insertion of a screw.

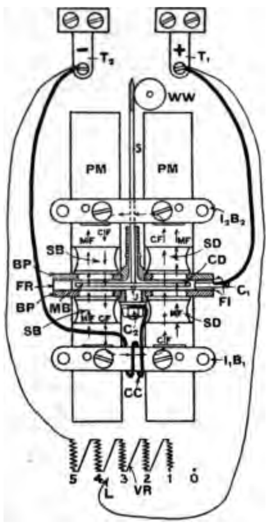


FIG. 54.—ELECTRICAL AND MAGNETIC CIRCUITS. NEW TYPE FERRANTI METER.

The armature CD, which at the same time serves the purpose of brake disc, consists of a circular disc of copper, platinum-plated except at its edge and centre, where it is amalgamated. The disc is mounted on the steel spindle S, which runs on a jewel, J (Fig. 54). This jewel is easily removed for inspection. The tendency of the armature to float is just balanced by a weight, W, fixed on the spindle, and the balance of the moving portion is adjusted by the nuts N (Fig. 53).

There are two pairs of pole pieces, one for each of the permanent magnets PM. The two top poles and the two

bottom poles are bridged across respectively by the iron bridge pieces I_2B_2 and I_1B_1.

The current to be measured passes from the positive terminal through the contact C_1 in the fibre ring, through the mercury to the edge of the disc. Leaving the disc at its centre, it flows to the contact C_2, round the few turns on the bridge piece to the negative terminal. The poles SD provide the driving flux, which, acting on the current in the disc, produces the necessary driving torque. The brake torque is produced by the fluxes of both magnets acting on the eddy currents in the disc produced by the rotation. The driving force being proportional to the current and the brake force proportional to the speed, the speed would be proportional to the current if it were not for the fluid friction due to the mercury and the solid friction of the counting train and bearings. The latter is very small, and the former, which becomes more important as the speed increases, is compensated for by means of the compensation coil CC. The flux produced by the main current through this coil is shown by the arrows CF. This flux, therefore, increases the flux in the right and decreases that in the left-hand mercury gaps, and, since the flux in the one is increased by the same amount as that in the other is decreased, the magnetic brake force is unaltered by the current in the coil CC, whilst the driving flux is increased as the current in the coil becomes larger, so compensating for the fluid friction. In this way the curve can be obtained within 2 per cent. at all loads between one-tenth and full load. The main spindle has a worm cut on its upper end which gears with the worm wheel WW (Fig. 54), and drives the wheel train. By the insertion of suitable change wheels the dials are made to indicate B.T. units without the use of a constant. An adjustment of 5 per cent. can also be effected by means of a variable resistance, VR, connected as a shunt across the poles of the meter. The steps of this resistance are so proportioned as to allow 0, 1, 2, 3, 4 or 5 per cent. of the current to be shunted from the armature, thus reducing the speed by these amounts.

The meter has a very small drop, that of a 5-ampere meter being 0·18 volts. The starting current of a meter of this size is stated to be 0·06 amperes. The meter being provided with

a $\frac{1}{10}$ths dial and a revolving disc by which $\frac{1}{100}$ths of a unit can be read, a test can be made in a short time by a dial reading.

The Hookham Meter.—The Hookham meter for continuous-current supply consists of a motor in which the main current is lead into an armature by means of mercury, the armature being immersed and partially floated in this liquid. Fig. 55

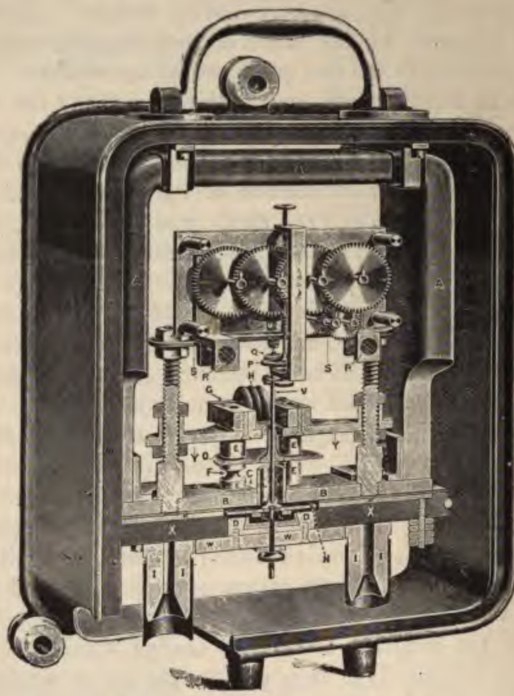


FIG. 55.—1897 TYPE HOOKHAM METER.

is a sectional drawing showing the principal portions of the meter known as the 1897 type. A permanent magnet, AAA, which consists of a bent bar of tungsten steel, provides the magnetic field for the motor and also the brake. The ends of this magnet rest on two soft iron pieces, BB, which are separated from each other by a brass piece, C. The lines of

force here divide, some flowing up through EE and the bridge piece G, forming the brake field in which the brake disc O rotates, and others down through the armature N to the bridge piece DD and up at the other side, thus passing through N twice, cutting it in the opposite sense.

The current is led to the mercury by the copper strips KK (the mercury being insulated from the sides of the chamber except at the ends of K). It then passes through the armature N, which is slit radially for about one-third of its diameter, being left solid at the centre. The object of the slits is to cause the current to flow diametrically across the disc in the magnetic field, the pole-pieces each embracing about one-third of the periphery of the disc.

If friction, other than the magnetic friction due to the brake, were negligible, the speed would be exactly proportional to the current, and the curve would be a straight line; but the meter possesses fluid friction, due to the mercury, in addition to the solid friction, due to the wheel train and bearings of the armature spindle. The fluid friction is proportional to the square of the velocity at slow speeds, but, increasing more rapidly as the speed increases, a compensation has to be introduced to eliminate errors due to this. This compensation is effected by the two or three turns H placed round the bridge piece G, which tend to reduce the brake field as the current increases. Should a meter be found to register low at high loads only, either the turns of H may be increased or the bridge piece G may be brought into closer magnetic contact with the cross bars on which it is fixed in cases where a slight gap has been left (filled with vulcanised fibre or other non-magnetic washers).

The curve can be raised or lowered slightly by raising or lowering the plate Y, thus increasing or reducing the brake air-gap. The iron bridge piece D can also be turned through a small angle by loosening the square lock-nut underneath W. The meters are, however, fitted with change wheels of various ratios, instead of being calibrated to a fixed speed, and consequently all meters of a size do not run at the same speed for a given load, a point which renders testing (especially testing in situ) somewhat more complicated. Moreover, great care must be taken to ascertain that the given constant is correct,

either by an accurate dial run or by counting the teeth on the change wheels.

A clamping gear is provided, consisting of a rubber washer, which, on being released by unscrewing the small milled nut in the front (not shown in Fig. 55), rises up underneath the disc and closes the mercury chamber. This arrangement has been found to be not altogether satisfactory. The rubber washer is liable to stick to the disc when unclamped, and also perishes after a time. This meter, in common with all other

FIG. 56.—1,000 AMPERE HOOKHAM METER.

meters which contain a liquid in an open chamber, is liable to be entirely altered if any of the liquid be spilled in its journey from the test room to the consumer's premises. In sizes above 100 amperes the meters are provided with shunts for carrying the greater part of the current, only a definite fraction passing through the meter itself. In such sizes the meter is either placed on top of the shunt, as in Fig. 56, or for switchboard use it may be mechanically separated from its shunt.

The torque of motor meters containing mercury cannot be measured with accuracy owing to the impossibility of effectually preventing the mercury rotating. When the disc is held up the mercury will rotate, and the friction against the held-up disc will create a torque tending to drag the disc round with the mercury, so that results obtained will be in excess of the torque. This important factor will also be somewhat different in different samples. The following results were, however, obtained on meters of different sizes :—

Size.	Full load torque in gramme-centimetres.
10 amperes	2·4
25 „	4·9
50 „	9·45

The 1901 type of Hookham continuous-current meter is made in sizes up to 10 amperes capacity, and is the same in principle as the 1897 type meter, the arrangement being different with a view to reducing the price. In this type the armature and brake discs are replaced by a single cylindrical copper bell, A (Fig. 57), which is completely immersed in mercury in the annular chamber H. The permanent magnet MMM produces the field, and the current, led from the positive terminal, enters the mercury bath at G, passes down through A, and leaves the mercury bath by the screw F. Eddy currents are also produced in A, due to its rotation in the magnetic field; thus the bell serves the double purpose of driving armature and brake disc. In the larger sizes the current on leaving F passes through the coil on the soft iron bridge piece V, which compensates the error caused at high speed, due to the fluid friction of the mercury. As will be seen, it forms a magnetic shunt to the field through the armature—*i.e.*, that flowing between KL—weakening this field more and more as the current increases. This compensating device, therefore, reduces the Foucault brake force relatively to the driving force, but at the same time reduces the driving force and consequently the torque. Adjustment is made by altering the number of turns of the coil in circuit.

Two balance weights, Q and R, are fixed to the main spindle to prevent the bell A from floating off the supporting pivot E. The mercury bath is covered by the ebonite piece P, to the

underneath of which is attached a soft rubber washer, W. When the meter is clamped for transport the balance weight Q is raised up against this washer and closes the mercury chamber. Only a portion of the clamping gear is shown in the figure—viz., the two prongs S fixed to the shaft. The prongs are raised by turning the shaft by means of a long crank on

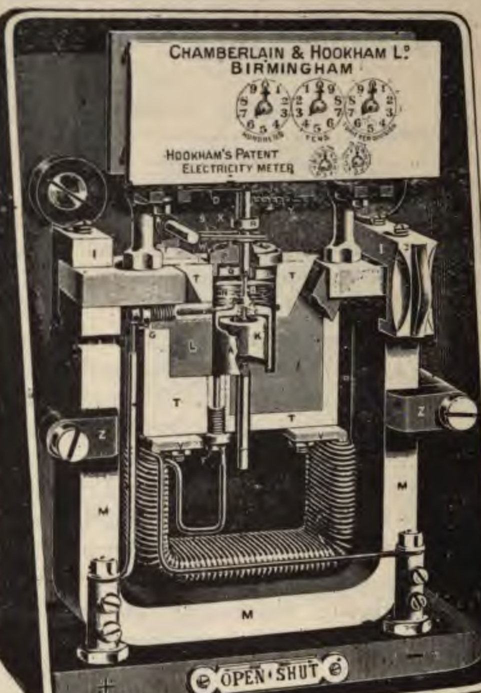


FIG. 57.—1901 TYPE HOOKHAM METER.

the front end of the latter, which comes down and terminates in a pointer just above the label on the base plate, indicating when the mercury bath is open or shut. The prongs engage with the balance weight R, thus raising the spindle and closing the mercury chamber. The torque of this meter is very low indeed; from tests made by the Author it has been found to be

as low as 0·35 gramme-cm. at full load on 3-ampere meters. The mechanical friction of the main moving portion, being partially floated as it is, must be small, but it seems from numerous tests made that the wheel train friction is large and variable. This, owing to the small torque, seems the cause of results differing from each other being obtained. The curve also depends considerably on the compensation.

A plate screwed to the front of the meter enables the meter to be connected up to the circuit, and the unclamping to be performed without breaking the seal on the main cover or door.

The same remarks apply to measurements of the torque of this meter as to the 1897 type and, in fact, of all motor meters containing mercury.

The Hookham Continuous-current Watt-hour Meter.— Fig. 58 illustrates the Hookham continuous current watt-hour meter brought out in 1904, chiefly for switchboard use. This meter is also a mercury motor meter, and although differing considerably in appearance from the ampere-hour meters made by Messrs. Chamberlain and Hookham, the only important difference is the addition of an electro-magnet capable of quick response to variations of voltage, which dispenses with the usual permanent magnet of the ampere-hour meter for supplying the driving field.

In this meter, as in the 1897 ampere-hour meter previously described, the armature and brake disc are quite distinct. The armature consists of a bell similar in shape to, but considerably larger than, that of the 1901 type ampere-hour meter. It is mounted near the lower end of the main spindle, and is immersed in the mercury bath. The brake disc consists of a flat circular disc of aluminium mounted higher up on the main spindle, and rotates between the poles of two permanent magnets. The arrangement of the parts is seen in the half-sectional elevation, Fig. 59, in which the main spindle A carries the brake disc B and driving disc C. D_1, D are the two permanent magnets which supply the brake field, and E the electro-magnet, which is energised by a shunt current passed through the coil F, and which supplies the driving field. As will be seen the pole piece of E projects up into the mercury bath and into the driving cylinder C, in order that as many

lines of force as possible may pass through this cylinder. The return path of these lines is through the air. The core of the electro-magnet is built up of a number of washers, E_1, E_2, &c., with insulation between them, and is thus formed of a number of magnets whose lengths are short compared with their areas of cross-section. The demagnetising effect of such a combination is great, and consequently the strength of field is quickly altered with any change of current through the magnetising

FIG. 58.—HOOKHAM CONTINUOUS-CURRENT WATT-HOUR METER.

coil. The main current is led to and from the mercury bath by the leads G, and passes through the vertical side of the cylinder C, thus cutting the shunt field. The mercury chamber is bored out of a block of ebonite, H, and is covered by a metal cap. The meter is constructed to carry 50 amperes and in larger sizes is used in conjunction with a shunt.

A measurement of the full-load torque of a 200 volt 50-ampere meter gave the value as 4·6 gr.-cms., to obtain which

the meter has a high shunt loss. The shunt current of this meter was 0·1 amp., which means a shunt loss of 20 watts. The drop is low, being 0·15 volt at full load. The curve is a very good line. This meter was only 0·6 per cent. slow at $\frac{1}{25}$th of full load and started on ·2 amp.

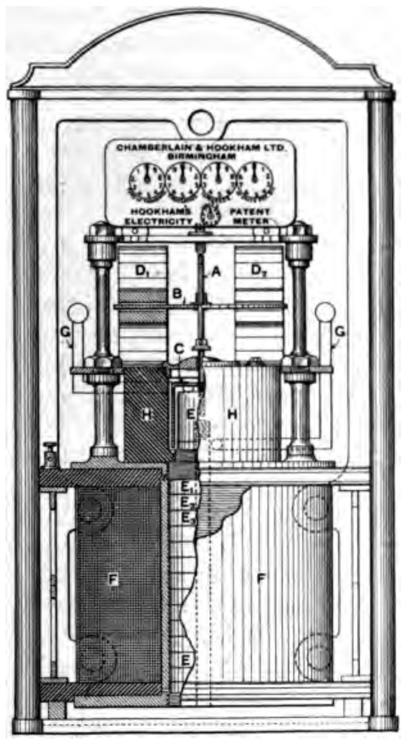


FIG. 59.—HALF SECTIONAL ELEVATION OF HOOKHAM WATT-HOUR METER.

The "O K." Continuous-current Ampere-hour Meter.—The "O.K." meter, brought out some years ago by the British Thomson-Houston Co., has been improved from time to time, and is a very good little meter for circuits of from 1 to 15 amperes. It is somewhat similar in principle to the Electrical Company's

ampere-hour meter, the chief difference being that the armature coils, instead of being laid on a metal cylinder, are, in the "O.K." meter, laid on a non-metallic one. The Foucault brake is, therefore, absent. Fig. 60 shows the latest type of this meter, and, as will be seen, the armature rotates between the poles of a strong inverted horseshoe magnet. The cylinder, on the outer surface of which the four armature coils are laid, is hollow, and, being fixed to the main spindle at the bottom only, allows a tube of iron to be placed inside it which reduces

FIG. 60.—LATEST TYPE OF O.K. METER.

the air-gap. Enough clearance is left at either side to allow the armature to rotate without touching the magnet or this "keeper." The main spindle passes down through the centre of the tube, and the commutator is fixed on its lower end. The bottom of the spindle is polished and rests on a spring-seated jewel, whilst a worm on the upper end of the spindle works the wheel train. The brush gear is extremely neat: each brush is stamped out of a piece of silver and loosely slid on a small rod forming the brush support. The required tension is produced by a fine spiral spring, one end of which is fixed

to the brush and the other to an adjustable clamp which grips the bottom of the brush-supporting rod.

The main current passes through a short length of platinoid wire so chosen as to have a drop of about 0·5 volt at full-load. The armature is in parallel with this wire; when a current flows the armature runs up to a definite speed, accelerating until the back E.M.F. nearly equals the E.M.F. supplied to the brushes due to the drop in the shunt. In this condition there is only just enough current taken by the armature at an extremely small voltage to overcome the static friction.

The armature rotates at a very high speed (as high as 250 revs. per min. at full load in some sizes), and thus friction, even at low loads, has very little effect. The torque also is so large, being about 28 gramme-cm. at full-load, that increase of friction seems to have very little effect except at the smallest loads. There being no compensation for friction the curve droops slightly at low loads. A difference of 2 to 2½ per cent. has been found to be a usual figure between full and one-tenth loads. The moving system is heavy, weighing about 213 grammes.

The meter is adjusted at high load by increasing or decreasing the pressure across the armature by shifting the little connector (seen to the right of Fig. 60) down or up the platinoid shunt. The dials of these meters, as will be seen from the figure, are very bold and their value plainly marked. The three black dials indicate fractions, and 0·0001 of a Board of Trade unit is easily read, for the last dial is divided into a hundred parts. It is thus quite easy to get a very accurate test by a dial run in a few minutes. The meter is very useful as a testing instrument, for instance, for ascertaining the ampere-hours passed through other meters or apparatus during a long run, thus avoiding constant regulation of the current. The accuracy with which it can be read, together with the ease with which its constant can be checked during a run, render it very suitable for such work.

The cover beds in a groove in the back fitted with felt and forms a dust-tight joint. A hole in the bottom of the cover allows the brush bracket, commutator and jewel screw to project below for easy inspection without breaking the main cover seals. A dome covers this gear up and is sealed up by the same seal as the terminal box cover.

The Reason Meter.—This meter, which is another example of the mercury type of motor meter, is chiefly made as a pre-payment meter. The action of the meter depends on the rotation of a copper disc or armature immersed in a bath of mercury in a magnetic field. Fig. 61 is a front elevation of the meter out of its case, whilst Fig. 62 is a sectional view looking at the front half. In this meter there are two distinct magnetic fields. One is constant and practically closed, and consists of the two iron plates, A and B, joined together by hardened steel pillars, CC (which are

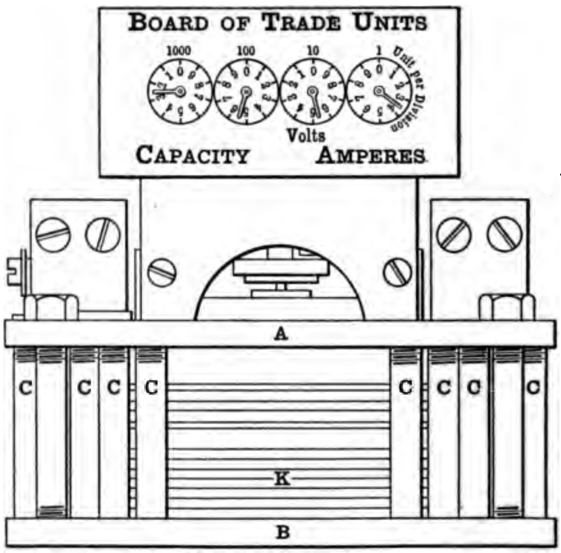


FIG. 61.—FRONT ELEVATION OF REASON METER OUT OF CASE.

permanently magnetised), the soft-iron pole-pieces E_1 and E, and the soft-iron core D. This field has its greatest effect at low loads, causing the meter to start well.

The second magnetic field is that generated by the main current passing through the coil K wound round the soft-iron core D. This field also passes through the mercury bath and the plates A and B, which are separated by the large air-gap (the permanent magnets C being saturated). The open magnetic circuit has the advantage of doing away with

residual magnetism, and also enables the meter to be overloaded without the curve being seriously altered. The surfaces of poles-piece E and E_1 are coated with insulating material between their edges and the top of their slant.

The current passing from the positive terminal through the iron and steel parts enters the mercury bath at the centres of the pole pieces; it then flows radially through the bath and disc (at right angles to the field) to the ring F, to which one end of the coil is soldered, and through the coil to the negative

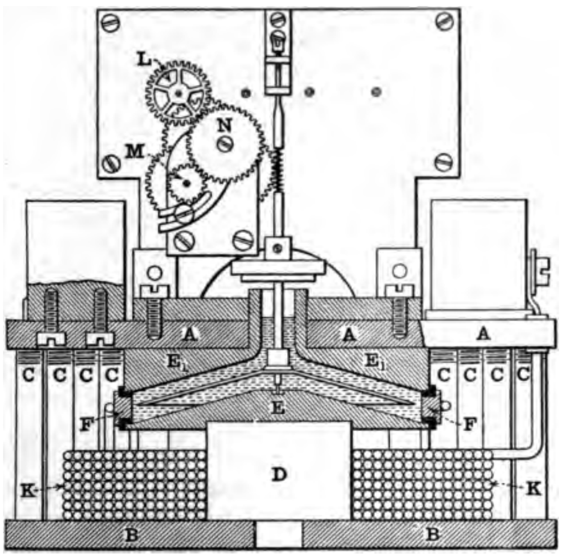


FIG. 62.—SECTION OF REASON METER LOOKING AT FRONT HALF.

terminal. Eddy currents generated in the same disc provide the necessary brake force. The field strengths are so proportioned that no adjustment of the curve is necessary, and the raising or lowering of it is done by the insertion in the wheel train of change wheels of different ratios in order that the reading may be Board of Trade units without using a constant. The change wheels may be replaced without taking off any other part of the wheel train, thus avoiding any chance of introducing friction, when replacing, by leaving the worm and

worm-wheel too tight in gear. The disc and bath are made conical, and as the disc is open at the top of the cone there is little chance of air bubbles remaining under it and so interfering with the low-load results. The meter is open to the objection of all meters which contain mercury—namely, it entirely depends on what happens to it in its journey from the test room to the consumer's premises if sent out with its main cover sealed. The meter is also made with the permanent magnet field replaced by an electromagnetic field produced by a shunt coil connected between the two supply mains. With such meters it is necessary to exercise care in connecting them into circuit, as the shunt field may be connected up so as to act in opposition to the main field. The meters are internally connected up for the main terminals to be put on the positive main—*i.e.*, the positive main terminal to the "station" side of the positive main and the negative main terminal to the "house" side of the same main, the shunt terminal being connected to the negative main. If the meter is to be inserted in the negative main, the ends of the shunt winding must be reversed, as in this case the shunt terminal will be connected to the positive main of the supply.

The constant marked on the back of the clockwork is either the number of revolutions of the main spindle per ampere per minute or the revolutions of the main spindle for 10 Board of Trade units. The meter has a high torque for this class, with a rather high drop. From tests made on a 200-volt 5-ampere meter a drop of 1·55 volts and a full-load torque of 2·67 gramme-cm. were obtained. The static friction being very small, owing to the armature being almost floated in the mercury, and the wheel train well made, the constancy of the accuracy would probably depend more on the cleanliness of the mercury and the permanence of the magnets than on the increase of mechanical friction.

The Wright Electrolytic Meter.—This meter is a successful example of the shunted type of electrolytic meter. The main current is passed through a platinoid resistance from the positive terminal D to the negative terminal E (Fig. 63), and the drop across this resistance is about 1 volt at full load. In parallel with this wire is an electrolytic cell contained in a

hermetically-sealed glass tube of special design, having a resistance, P, in series with it. The resistances of the two circuits are so proportioned as to allow about $\frac{1}{200}$th of the main current to pass through the cell. The sealed tube contains a saturated solution of mercurous nitrate and a quantity of pure mercury. The anode A is formed by a ring of mercury, the cathode C being a hollow cone of platinum fixed below the level of the anode. In the more recent meters

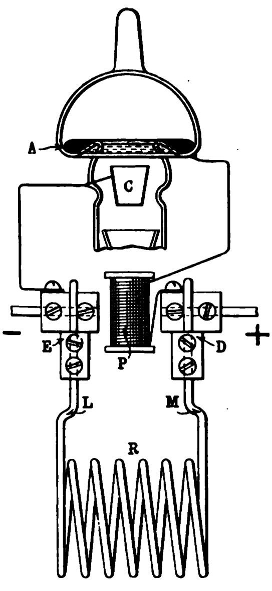


FIG. 63.

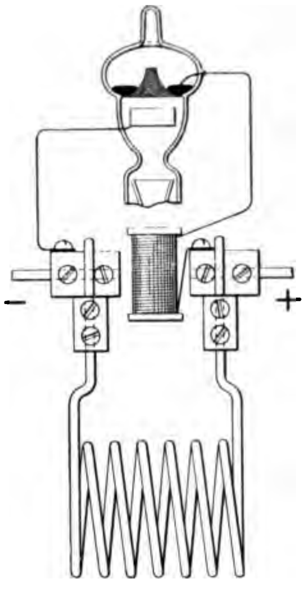


FIG. 64.

the anode holder has been modified as in Fig. 64. The ring of mercury remains, but instead of lying in the channel formed by the glass vessel, it rests partly on the glass and partly on a cone of platinum gauze of a fine mesh. With the former type of holder there existed a danger of mercury being shaken over the edge of the anode holder when the meter was subjected to a moderate amount of vibration. The deepening of the channel was a first step to remedying this defect, but the present

arrangement enables the meter to withstand excessive vibration without causing any mercury to fall over. The cohesive force of the mercury prevents any falling through the mesh.

On passing a current through the meter, the definite fraction which passes through the cell causes mercury to be deposited in small globules out of the solution on to the cathode. These globules fall off by gravity, and are caught by a glass funnel which forms the head of a narrow tube. The latter has a scale at its side graduated usually in 100 divisions, each corresponding to one Board of Trade unit; thus the amount of mercury deposited is taken as a measure of the energy passed through the meter, the pressure being assumed constant as in all ampere-hour meters.

In the larger sizes of meter this tube is made in the form of a syphon, so that, on the level of the deposited mercury reaching the 100 mark, it automatically syphons over into the bottom of the vessel in which a second scale is placed, each division of which corresponds to 100 units, or the contents of the syphon tube. This second scale, therefore, takes the place of a second dial in ordinary dial trains, and enables the meter to register up to 1,100 units, after which the record is lost and the meter requires re-setting to zero. This is done by tilting the tube about the hinged bracket by which it is supported at the top, thus allowing all the mercury to return to the reservoir F (Fig. 65), which automatically keeps the level of the mercury in the anode ring constant. As the mercury is precipitated from the liquid, so the weight of the latter is diminished, and in order to avoid the back E.M.F. due to difference in concentration of the electrolyte it is essential that the density of the liquid should be the same at all points between the electrodes. It is for this reason that the cathode is placed at a lower level than the anode, for then a circulation, shown by the lines in Figs. 65 and 66, is set up, the weakened liquid at the cathode rising and its place being taken by the replenished and heavier liquid near the anode. The back E.M.F., which is such an important objection in electrolytic meters, especially of the shunted type, is extremely small in this cell, and does not exceed $\frac{1}{10000}$th of a volt. As the drop at full load is about 1 volt, the error caused by the back E.M.F. would only be 1 per cent. at $\frac{1}{100}$th of full load.

In order that the ratio of the main resistance and the cell-circuit resistance may remain constant, it is necessary to compensate for temperature. This is done in the following manner: The electrolyte having a negative temperature coefficient, part of the extra resistance placed in series with the cell is of copper. The required amount is calculated so that the curve connecting the combined resistance of cell and wire with temperature (within wide limits) is a straight line, which gives a constant value for the resistance between 5°C. and 30°C. The total resistance in the cell circuit is then made up to the amount required for depositing a chosen weight of mercury

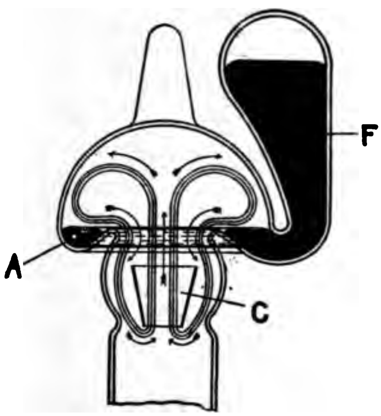


FIG. 65.

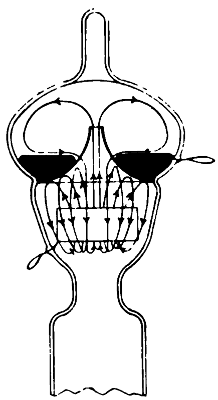


FIG. 66.

per Board of Trade unit passed through the meter; the "making-up" resistance is of the same material as the main circuit, which is usually platinoid. Final calibration is effected by sliding the main resistance up or down in the terminals, about $\frac{1}{4}$in. making a difference of 1 per cent. These terminals should be sealed after final adjustment is made, as the case has to be opened each time the meter is set to zero.

Fig. 67 illustrates this meter with the single tube (sizes $2\frac{1}{2}$ to 5-ampere), whilst Fig. 68 shows the larger meter in which the syphon tube with its scale is seen above the second tube with its hundreds scale.

Figs. 67 and 68 are illustrations of the gauze type meters, and, as will be seen, the meters are suspended in their cases by four spiral springs. A fifth and weaker spring, terminating in the ring seen underneath the scale, holds the meter in its

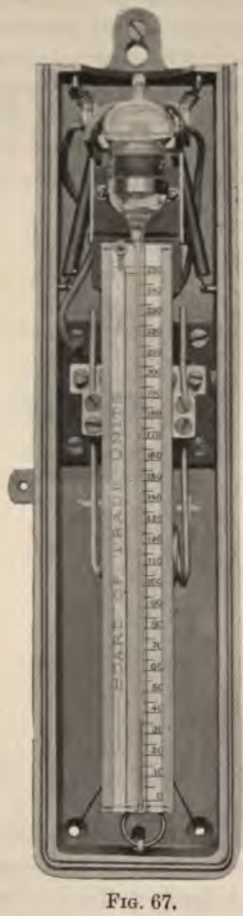


Fig. 67.

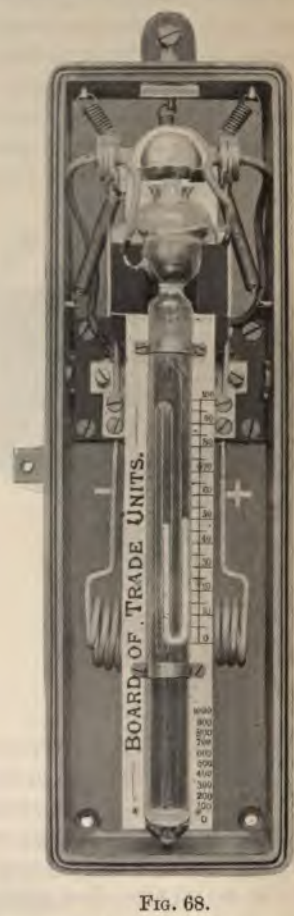


Fig. 68.

working position when the ring is passed under the hook fixed near the bottom of the case.

For three-wire installations, where these consist of two distinct two-wire circuits brought down to the meter, the main

resistance of the meter is divided into two exactly equal parts, the electrolytic cell, with its extra resistance bobbin, being connected to its ends as in two-wire meters. The meter is inserted at the point where the neutral is split, as in Fig. 69, and will give a correct indication of the total Board of Trade units on circuits of constant voltage. For if R_1 and R_2 are the resistances of the two halves of the meter main circuit in which the currents C_1 and C_2 flow, the P.D. across $R_1 + R_2 = V$, and $V = C_1R_1 + C_2R_2$; and, as $R_1 = R_2 = R$, $V = R(C_1 + C_2)$. Thus the current through the electrolytic cell will be proportional

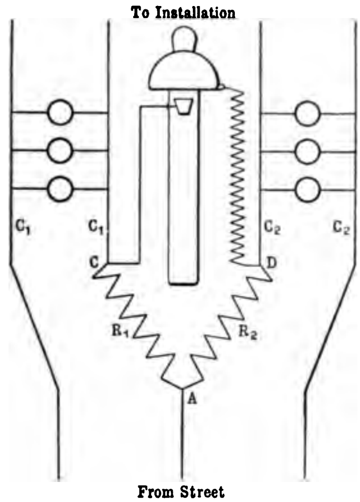


FIG. 69.

to the sum of the two currents. It is, however, essential that the wiring be split up into two independent circuits on the "house" side of the meter.

Amongst the few objections to this meter may be mentioned the difficulty of ascertaining its accuracy on account of the time it takes to pass even the full-load current to produce a reading sufficiently large to eliminate errors in readings. The syphoning point also requires testing to ascertain that the syphoning takes place when the mercury reaches the top mark on the scale. It is possible to shake mercury into the syphoning tube to a reading of about 90 and start this test from that

point, carrying it on over the syphoning point until a fair reading is obtained. A little sleight of hand is necessary for this operation in the case of the gauze type meters. The wiping out of all record on resetting to zero may lead to disputes, as may also the loss of the final reading on removing the meter from the consumer's premises before it has been checked by the testing department. If connected up in the wrong way the outer glass tube is very liable to crack, when the meter becomes useless until refitted with a new tube and contents.

CHAPTER IV.

METERS SUITABLE FOR BOTH ALTERNATING AND CONTINUOUS CURRENT.

With but few exceptions, such as the Aron and the Mordey-Fricker, all meters suitable for working on both alternating and continuous-current circuits are motor meters, having a wound armature with a commutator and brushes connected through a high and practically inductionless resistance across the supply mains, the armature being placed in a field produced by the main current passing through a fixed coil or coils. Two fields are therefore produced: one, by the armature, proportional to the current through it, which is again proportional to the supply voltage, and the other proportional to the current in the field coils, which is the current supplied to the lamps, &c.

The brushes are placed on the commutator at such an angle that the armature field is approximately at right angles to the main-current field, with the result that a torque is produced tending to bring the coils into the same plane. The commutation causing the fields to be permanently at the same angle, the torque remains, and the armature rotates so long as there is current flowing through the main coils. A metal disc attached to the same spindle as the armature rotating between the poles of permanent magnets usually provides the necessary retarding torque for the production of a speed proportional to the watts transmitted, if mechanical friction be so small as to be negligible.

The mechanical friction, which is relatively high in this type of meter, although kept as low as possible, would not be

negligible at low loads. It is therefore compensated for by passing a small current through a compounding coil placed in the same plane as the field coils, thus producing a permanent field which would, if strong enough, overcome all mechanical friction. In practice this device is open to objections. The compensation cannot be complete, as the mechanical friction depends to a large extent upon the external vibration, such as that due to street traffic or other causes. A meter compensated in a situation where there is no vibration would run, due to the compensation torque, when installed where vibration existed. It is evident that such troubles become less in meters having a high driving torque, for in these it is unnecessary to compensate so completely to obtain the same accuracy at low loads.

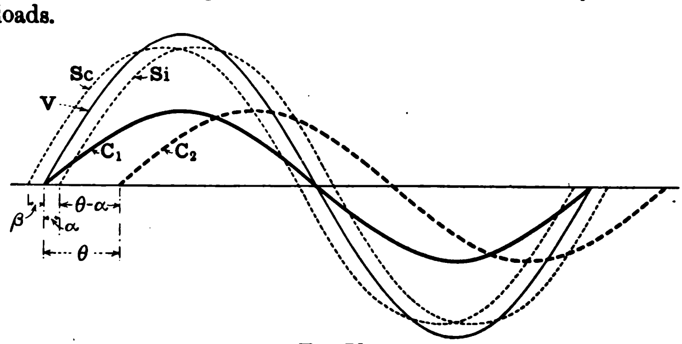


FIG. 70.

The accuracy with which meters of this type register on alternating or continuous-current circuits without special calibration depends on the self-induction and capacity of the shunt or armature circuit. The armature will have self-induction, and, consequently, requires a high resistance in series with it, so that the ratio of resistance to self-induction of the combination may be large; otherwise the meter will under-register on alternating-current circuits of unity power factor when calibrated on continuous current. If, in Fig. 70, V represents the curve of current in the shunt-winding, if in phase with the voltage, and C_1 the main current curve (on a smaller scale) in phase with V, so that the power factor is unity, then the curve S_i would represent the curve of current in the meter shunt or armature circuit, if it were lagging by a small angle,

α, behind the voltage owing to the self-induction of the armature circuit. The current in this circuit will also be reduced in the ratio of the resistance to the impedance; consequently the torque, and therefore the speed, will be lower than it should be. When the current in the main lags by the same amount as the current in the shunt the speed will be correct. If the angle of lag of the main current is greater than that of the shunt current, as shown by the current curve C_2, which lags by an angle, θ, behind the voltage curve, the speed will be high and the meter will over-register, its error becoming greater as the power factor of the circuit becomes lower. The meter would still register when $\theta = 90$deg., that is, when the power factor $= 0$, for the angle of lag between the currents in the shunt and main circuits would be $\theta - \alpha = 90 - \alpha$ instead of 90deg.

The non-inductive resistance which usually forms a great part of the shunt resistance may have sufficient capacity to have a preponderating influence over the self-induction of the circuit, in which case the current in the shunt circuit would have a lead as shown in Fig. 70 by the curve S_c. In this case the meter would still under-register on a circuit of unity power factor, for the shunt-current curve would be out of phase with the curve V, and the error would become greater the more the main current lagged. The meter would stop altogether when $\theta + \beta = 90$deg., instead of when $\theta = 90$deg. Such a meter would rotate backwards, showing a negative consumption, when the angle of lag of the circuit became greater than $90 - \beta$.

In practice α or β is a very small angle, and, consequently, the error introduced either by the self-induction or the capacity of the shunt circuit does not become very important in the measurement of the energy supplied to either non-inductive or inductive circuits of the power factors usually met with in practice, which are usually above 0·5. Meters of this type should, however, be tested on alternating current if at all likely to be installed on such circuits, as defects may be overlooked if tested on continuous current which may make as much as 50 per cent. error on alternating current. Meters of the same type, but of different sizes, may have different errors on the two currents, and on inductive circuits. This is very likely to occur if the shunt current is not the same in all

sizes, for the alteration of the shunt current would probably be produced by altering the amount of resistance in series with the armature without any alteration to the armature itself; consequently a change would be made in the shunt circuit which would produce different results in meters of different sizes of the same make owing to the alteration in the ratio of the resistance to the self-induction of the shunt circuit.

The question as to whether the self-induction or the capacity of the shunt circuit will preponderate depends in some measure as to how the resistance in circuit with the armature is built up. The resistance will possess maximum capacity if the wire is wound double, in a manner similar to the bobbins of an ordinary resistance box or Wheatstone bridge. If, however, the resistance is wound in a number of sections on a card or flat piece of insulating material, it will possess smaller capacity the greater the number of sections into which the resistance is split up. It might, therefore, be possible, if the self-induction of the armature were not too large, to provide a resistance in which the capacity could be made to neutralise exactly the self-induction of the circuit by winding certain proportions of the resistance in the two ways mentioned above. If this were done to a nicety, a meter could be made accurate on extremely low power-factor loads.

The driving torque should be uniform throughout the revolution, otherwise the starting current will be higher in some positions of the armature than in others. The speed also at low loads is enormously affected by an uneven driving torque, which is of little consequence at high loads. At high speeds the momentum of the moving part is sufficient to cause a practically uniform speed for the complete revolution proportional to the mean of the different values of the torque, but as the load is reduced the speed does not remain proportional to the mean value. During that portion of the revolution when the higher torque exists the speed will be higher than the normal, and it will be lower than the normal on that portion of the revolution during which the lower torque is operative. The armature in turning into the position of low torque slows up, and, consequently, takes longer time to turn through the same angle as when acted on by the high torque. The error introduced increases as the load decreases, becoming

infinite when the load is so small that the meter stops when in the low-torque position, although at this load the speed may be quite definite in the high-torque position.

The Aron Meter.—The original form of Aron meter was an ampere-hour meter. Two hand-wound clocks, each provided with a long pendulum, were connected by means of a differential gear to a recording train in such a manner that the speed of the latter was proportional to the difference in the number of oscillations of the two pendulums. The one pendulum was of brass, and oscillated always at normal speed, being acted on by the influence of gravity only; whilst the other pendulum had a magnet at its end which oscillated over a coil through which the main current was passed, and, acting on the magnet, accelerated the pendulum. When no current was passing the two pendulums were synchronised so as to oscillate at the same speed. The accuracy of the meter depended to a very large extent on the normal speed of the two pendulums remaining constant. In the modern Aron meter, which is a watt-hour meter, much shorter pendulums are used, and each has a coil of very fine wire at its swinging end through which the shunt current is passed. The main current is led through two fixed coils underneath the pendulum coils, accelerating one and retarding the other. The shortening of the pendulums, and both being influenced by the current, allows of greater sensitiveness owing to the production of a greater difference in the number of oscillations by a given current in a given time.

Fig. 71 shows the Aron meter in a switchboard type case, and gives a good view of the internal arrangement of the meter. The main coils are fixed as seen, by brackets to the back of the meter. Above them the angle brackets which support the clockwork are also firmly screwed to the back. The clockwork is fixed on the bracket in such a position that the axes of the pendulum coils and the corresponding main coils are in the same vertical lines when the pendulums are at rest and the meter is level, as indicated by the plumb bob, which is fixed to the clockwork in front of the dial face. Behind the clockwork is the winding gear, which is also screwed on to the back of the meter. The

non-inductive resistance in series with the pendulums is wound on porcelain reels, seen in the top corners of Fig. 71.

The clockwork, which is beautifully made, is very complicated, and consists of the following mechanisms :—

1. Two trains transmitting the driving power from the mainspring to the pendulums and connected together by a differential gear which actuates the counting train.

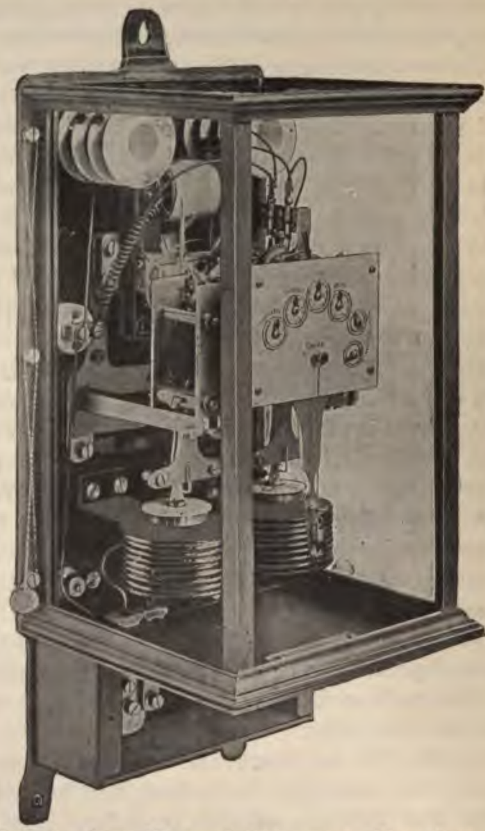


FIG. 71.—ARON METER IN SWITCHBOARD TYPE CASE.

2. Reversing gear for reversing the direction of rotation of the recording hands when the direction of the current in the pendulum coils is reversed.

3. Mechanism for the quick reversal of the commutator and reversing gear.

The main-spring acts on the two pendulum trains through a differential gear shown in Fig. 72. The two vertical wheels are loose on the spindle and are in gear, one with the first wheel of one pendulum train and the other with the first wheel of the other pendulum train. The planet wheel, being free to revolve on its spindle, whilst transmitting the power to the two clock trains, does not interfere with their speeds, for when the speeds are not the same the planet wheel will

Fig. 72.—Aron Meter. Differential Gear.

Fig. 73.—Aron Meter. Reversing Mechanism.

rotate. A similar differential gear connects the counting train to the two clock trains; in this case the vertical wheels are driven in opposite directions, and the counting mechanism is driven by the horizontal spindle. When the speeds of the two clocks are the same, the planet wheel simply rotates without turning the horizontal spindle, but, when the speeds are different, the planet wheel runs round, its rate of revolving depending on the difference in speeds of the two pendulums. Between the horizontal spindle just referred to, and the first dial of the counting train, is the reversing gear, seen in Fig. 73,

in which the wheel on the left is rigidly fixed on the horizontal spindle of the differential gear, and the one on the right is the first wheel of the counting train. The two small wheels next to the left-hand wheel are loose on spindles fixed to the plate. The other three wheels, one above the other, are on spindles fixed to a bar which is rocked about the axis of the middle wheel of the three, and thus either the top or bottom wheel is thrown into gear according to the position of the bar. The travel of this rocking bar is controlled by stops which ensure the correct gearing of the rocking wheels. It will easily be

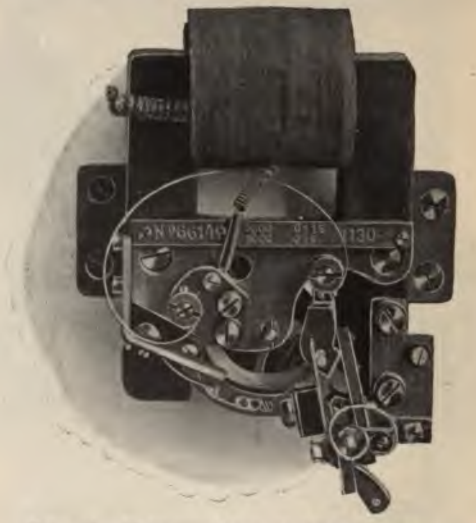


FIG. 74.—WINDING GEAR OF ARON METER.

seen that by this device the direction of rotation of the wheels of the counting train is reversed. The mechanism which rocks the bar, and at the same time turns the commutator through half a revolution, is seen at the top of Fig. 73. This ingenious device is also driven by the mainspring. In order to obtain a quick action of the reversing gear, a small spiral spring is gradually wound up and released every 10 minutes (11 minutes in the older meters), thus rotating the commutator half a revolution, as also the crank (Fig. 73) which is fixed on the front end of the commutator spindle. Thus the direction of the current

in the pendulums is reversed exactly at the same time as the direction of rotation of the recording hands.

The object of the above mechanism is to prevent any reading of the dials due to want of synchronism between the two pendulums when no main current is passing, which otherwise would take place. Any reading produced by this cause during one period of 10 minutes is wiped out during the next, but, on the other hand, any reading produced by the action of a current through the main coils is continuous during the complete

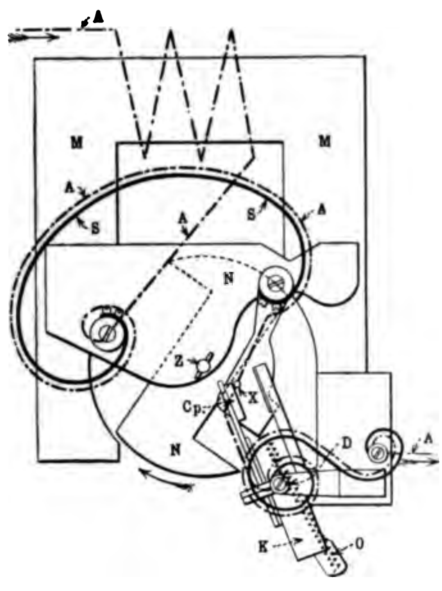


FIG. 75.—DIAGRAM OF WINDING GEAR IN NORMAL POSITION.

20-minute period. The main-spring and its winder are illustrated in Fig. 74. The action of the winding gear is seen by referring to the diagrams (Figs. 75, 76 and 77). This consists of a special form of motor, having an excited field magnet, M (Figs. 75 and 76), and a rotor, N, of Z-shaped iron stampings, which is rotated about a quarter of a revolution in a clockwise direction each time contact is made by the automatic switch K, which allows a small current to flow through the field magnet. The path of this current is shown by the dotted lines.

In Fig. 75 the mainspring S is seen in its normal position, and in Fig. 76 in its fully-wound state. The switch K being pivoted at D, has its upper end carried over by the pin X (against the pull exerted by the spiral spring O, Fig. 75) as the mainspring uncoils. When O passes across the centre of pivoting D, the silver plate Cp is quickly pulled by O up against X, thus making the electrical contact. One end of the mainspring S being rigidly fixed to N, as shown, as S unwinds, N is turned anti-

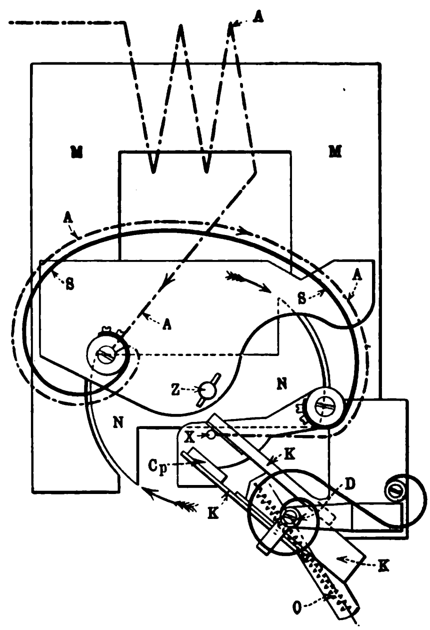


FIG. 76.—DIAGRAM OF WINDING GEAR. SPRING FULLY WOUND.

clockwise; consequently, on the making of the circuit N is at once attracted into the position shown in Fig. 76, thus rewinding the mainspring, and at the same time breaking the winding gear field circuit.

The design of K not only secures a quick make-and-break, but also a rubbing contact. The power of the spring is transmitted to the driving spindle Z by means of the ratchet and pawls seen in Fig. 77. The rotor N is loose on Z, and the latter

is held by the pawl P during the brief interval during which the rotor is winding up the spring, whilst the pawl P', fixed to the rotor, turns Z all the time the spring is unwinding. Z being connected by a coupling to the horizontal spindle of the differential gear previously described, the power of the spring is thus ingeniously transmitted to the clocks.

The Aron meter is equally suitable for alternating and continuous-current circuits, but owing to the magnet of the winding gear requiring different winding it is necessary to change the latter when a meter is changed from one supply to the other. The winding-gear magnet, moreover, requires different field coils for different periodicities where these differ considerably.

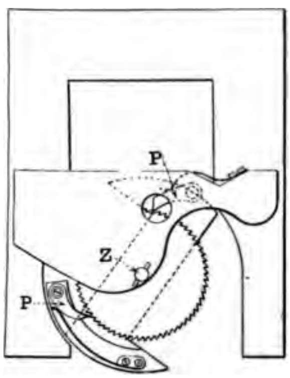


FIG. 77.

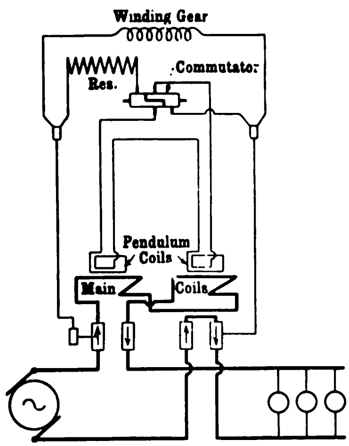


FIG. 78.

The connections for two-wire meters are shown in Fig. 78. For three-wire circuits one of the main coils is inserted in each outer, and a tee off the neutral is taken to a special terminal connected to the mid-point of the shunt resistance, as in Fig. 79. This gives the meter an advantage over other types of three-wire meters, as it enables it to take account of the pressure on each side, whereas in other cases the assumption is made that the pressure is equal on both arms of the three-wire system. The accuracy of the meter depends largely on its level, and consequently great care should be taken to instal

it absolutely plumb as indicated by the plumb bob. ' pendulums are self-starting when the pressure circuit is ma

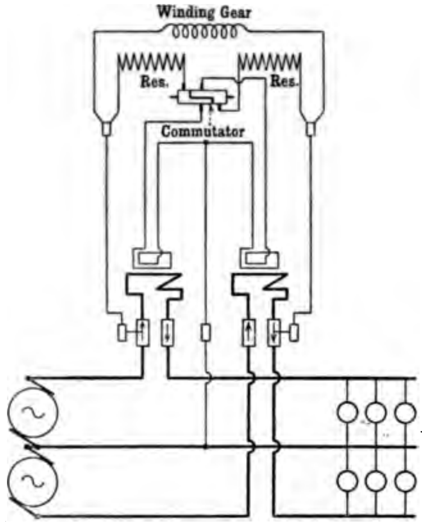


Fig. 79.

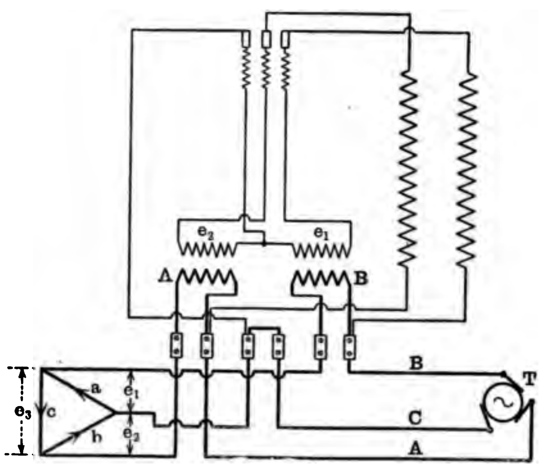


Fig. 80.

An objection to this meter is that if one pendulum stops any cause the reading is lost.

For measurement of the energy supplied to three-phase circuits the Aron meter is modified. For mesh circuits the meter is arranged as shown in Fig. 80, in which T represents the source of supply, A B C the currents flowing in the leads at any moment, $a\,b\,c$ the currents consumed in the mesh system at the sáme moment, $e_1\,e_2\,e_3$ the P.D.s as shown at the same moment. (The main coils of the meter are also marked A and B and the pendulum coils $e_1\,e_2$).

The work done at any moment in the mesh circuit is

$$W = ae_1 + be_2 + ce_3. \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

With three-phase currents

$$e_1 + e_2 + e_3 = 0,$$

$$c - b = A,$$

and

$$a - c = B;$$

and, by subtracting from (1)

$$c(e_1 + e_2 + e_3) = 0,$$

we get

$$\begin{aligned} W &= ae_1 + be_2 + ce_3 - c(e_1 + e_2 + e_3) \\ &= (ae_1 - ce_1) + (be_2 - ce_2) + (ce_3 - ce_3) \\ &= e_1(a - c) - e_2(c - b), \end{aligned}$$

and by the insertion of $c - b = A$ and $a - c = B$,

$$W = e_1B - e_2A.$$

The Aron meter, further modified as in Fig. 81, is made for the measurement of energy to star-connected circuits with neutral or combined star and mesh connections whether the phases carry balanced or unbalanced loads. For suppose, in Fig. 81, $i_1\,i_2\,i_3$ are the currents in the mesh connections, $E_1\,E_2\,E_3$ the voltages of these, $a\,b\,c$ the currents in the star connections, A B C D the currents in the leads and the neutral; then the watts at any moment in the combined connections

$$W = i_1E_1 + i_2E_2 + i_3E_3 + ae_1 + be_2 + ce_3. \quad . \quad . \quad . \quad (1)$$

Now

$$E_1 = e_3 - e_2,$$

$$E_2 = e_1 - e_3,$$

$$E_3 = e_2 - e_1,$$

and by inserting these values in (1) the following is obtained:—

$$\begin{aligned} W &= i_1(e_3 - e_2) + i_2(e_1 - e_3) + i_3(e_2 - e_1) + ae_1 + be_2 + ce_3 \\ &= e_1(a + i_2 - i_3) + e_2(b + i_3 - i_1) + e_3(c + i_1 - i_2). \end{aligned}$$

Now $A + i_3 - a - i_2 = 0,$

and, therefore, $a + i_2 - i_3 = A,$

also $b + i_3 - i_1 = B,$

$$c + i_1 - i_2 = C.$$

Thus, by substituting these values in the above equation,

$$W = e_1A + e_2B + e_3C. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

Now $e_1 + e_2 + e_3 = 0.$

$$\therefore \quad e_3 = -(e_1 + e_2).$$

Thus $W = e_1A + e_2B - (e_1 + e_2)C.$

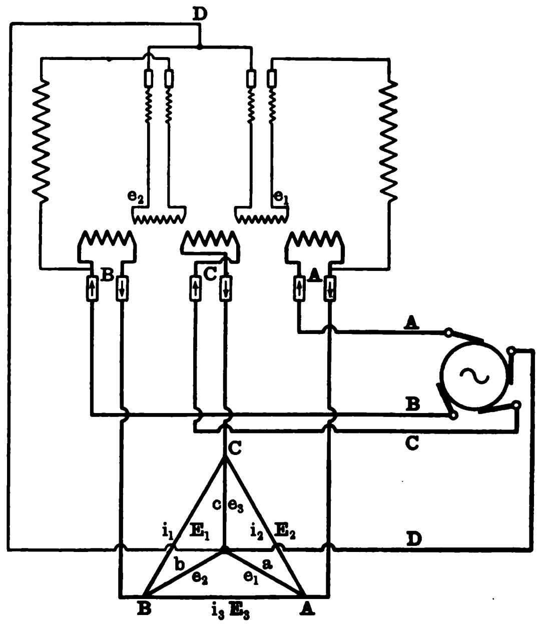


FIG. 81.

The pendulum coils of the meter, shown diagrammatically in Fig. 81, being suspended in a mid position between the main coils, each is affected by the coils on either side of it, and the current being sent through the middle coil C in the opposite way, the meter takes account of the minus sign of the term $-C(e_1 + e_2)$.

The Duncan Meter.—So far as the Author is aware, this meter has not been introduced into this country. Its theory is similar to that of other commutator motor meters, in which fields of force are set up at right angles to one another by the currents in the armature and in the fixed main coils, thus creating a torque proportional to the watts. The speed is controlled in the usual way by means of a disc running between the poles of two or more brake magnets.

The back casting, from which is supported the series field coils, registering train, and magnet support, is made of cast aluminium, containing about 10 per cent. of nickel to increase its mechanical strength and at the same time keep down the weight. The two main coils are held firmly in position by brass clamps secured to mounting plates, all of which are held in position by the four forwardly projecting brass rods. The front main coil can be easily removed for inspecting the armature and commutator. To do this it is only necessary to unscrew the two brass clamps which hold the coil against the forward mounting plate, and disconnect the ends of the coil at the terminals (Fig. 82).

The registering train, which is arranged to read in kilowatt hours, is mounted on a bracket, which is supported by the two upper of the brass supporting rods used for holding the main coils in position.

The armature, which is fixed on a hollow steel spindle, is wound with 8,000 turns of copper wire 3·14 mils in diameter, and is seen in Fig. 82. The commutator is mounted on the spindle above the armature. The brushes are made from hard-drawn sheet phosphor bronze 8 mils thick, with silver contact pieces at their ends where they bear on the silver commutator. The phosphor bronze strips possess ample spring to ensure a delicate and reliable contact.

A former type of this meter was fitted with brushes held on by gravity, but the "mechanical tension" arrangement has proved much more reliable, and therefore the gravity arrangement is no longer used. The brushes are mounted on a bracket of insulating material, which it is claimed does not warp under any changes of temperature. By the removal of two screws the brush bracket, with the brushes, can be removed for inspection or cleaning. To ensure accuracy at

low-load, the mechanical friction is compensated for by a compounding coil which is made adjustable, so that the exact amount of compensation may be made *in situ* according to the amount of vibration of the building in which the meter is installed. By this means "creeping" and slow running at low loads can be avoided. In most meters of this class this adjustment is usually made by altering the position of the compounding coil, bringing it farther away from, or nearer to, the armature. The position of the coil in this meter is kept

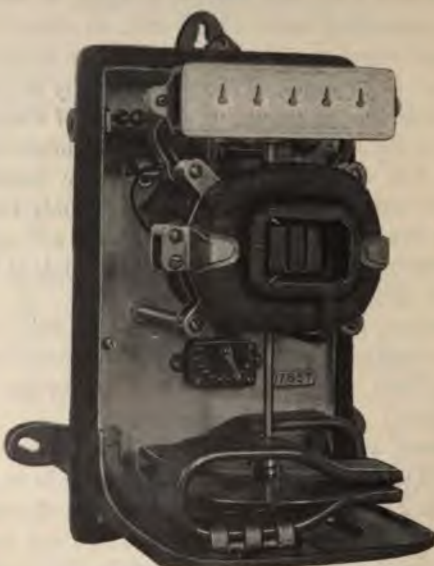


FIG. 82.—DUNCAN METER.

constant, however. It is wound with 1,000 turns of fine wire, which are subdivided into 10 equal parts by bringing out leads to a small compensating switch fixed to the back support. The switch and compensating coil (which is fixed inside the front main coil) are seen in Fig. 82. This compounding coil may be connected in series with the armature and the non-inductive resistance, in which case adjusting the coil slightly affects the value of the shunt current; but, as the resistance of the compounding coil is kept as low as possible, the alteration

of the number of its segments in circuit does not make a greater difference than one-half of 1 per cent. in the shunt current, and, consequently, in the error of the meter. The compounding coil is made an independent shunt circuit when desired, in which case adjusting it does not affect the current in the armature. It is then made of high resistance material.

The Duncan meter is provided with a very convenient form of jewel-bearing and pivot. The arrangement will be understood by reference to Fig. 83. In this sectional elevation, 1 is the main spindle, 5 the aluminium brake disc, the hub, 2, of which is split, as shown at *a*, and clamped by the ring 3 and

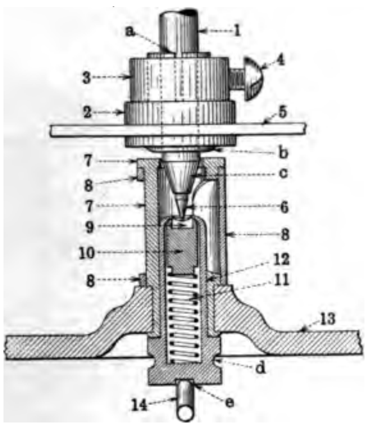


Fig. 83.—Sectional View of Visual Bearing and Threadless Jewel Post of Duncan Meter.

screw 4 to the spindle in the required position, so that, when the jewel post 12 is lowered, *b* just rests on the top, 7, of the jewel-post support. The jewel 9 is mounted in 10, which is supported on a spring, 11, the whole being inside the jewel post. This jewel post slides up into position and is not threaded, being held by a spring wire, 14, the latter resting in the groove *e* for working or in *d* when being carried. The support 7 is cut away at the side, as also is the collar 8, so that by turning the collar until the two holes meet, a view of the bearing is obtained. The pivot 6, which is held magnetically in the base of the spindle (the latter being magnetised for this

purpose), can be taken out for inspection through this window, using a pair of small tweezers. The small meters are provided with Ceylon sapphire jewels, and the large sizes with diamond bearings.

Eclipse Meters.—Types B.N.R., N.R., A.R., and R.R. of this meter are suitable for working either on continuous or alternating-current circuits; the last three types are similar except as to size. The B.N.R. and the N.R. are also very much alike, the chief difference being that the latter is provided with two main coils and two brake magnets, whereas the former has only one of each, thus reducing the drop across the meter, and also the torque, to half of what they would be with two main

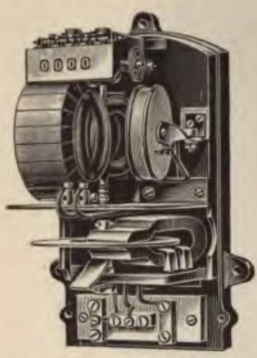


FIG. 84.—ECLIPSE "B.N.R." METER. COVER REMOVED.

FIG. 85.—ECLIPSE "N.R." METER. COVER REMOVED.

coils. The B.N.R. meter is seen in Fig. 84 and the N.R. meter in Fig. 85. In Fig. 84 the one main coil is seen to the left; its ends are brought down to the two outer terminal blocks fixed on the insulating plate at the bottom of the meter for which a separate cover is provided. The bobbin to the right carries the non-inductive resistance which is in series with the armature. Part of this resistance is wound inductively and forms the compounding coil. The bobbin is supported on a bracket which is clamped, by only one screw and nut, to an angle bracket fixed to the back casting; it can, therefore, be moved towards or away from the armature within certain limits for the purpose of adjustment, the screw acting as a

hinge. The chief difference between these meters and others working on the same principle is in the design of the armature, which is of the open type instead of the usual drum type. Fig. 86 is a view of the moving system, consisting of main spindle, commutator, armature and brake disc. The armature consists of three coils interlaced as shown. This armature, as will be seen, is somewhat different in form to those illustrated in Figs. 84 and 85, but it is the usual form supplied. One end of each coil is connected to one bar of the three-part commutator, the other ends of the three coils are joined together. Fig. 87 is

FIG. 86.—MOVING SYSTEM OF ECLIPSE METER.

a diagram of the connections in which A, B, C represent the three coils and K the commutator. Owing to the small number of commutator segments in comparison with the number required for a drum armature—three instead of eight or more—a considerable reduction in the diameter of the commutator, and consequent reduction in brush friction, would be possible if it were not limited by the diameter of the spindle. The diameter of these commutators is 0·2in., as compared with 0·25in. in the Thomson and 0·24in. in the Vulcan meters, which

have drum armatures. The chances of breakdown due to short-circuit or to breakages of the fine wires leading to the commutator bars are considerably reduced, however, as only three wires are taken to the commutator, instead of 16 in the case of an eight-segment commutator with a drum-wound armature. This type of armature is also much lighter than the drum; the torque, however, is variable for different positions in the revolution. The following figures were obtained according to the position of the armature:—16·7, 14·2, 12·7 grammes at a constant distance (the radius of the spindle). The above figures were obtained on a 200-volt 5-ampere B.N.R. meter, the mean full-load torque of which was 2·6 gramme-cm. The weight of the moving system is about 130 grammes. The

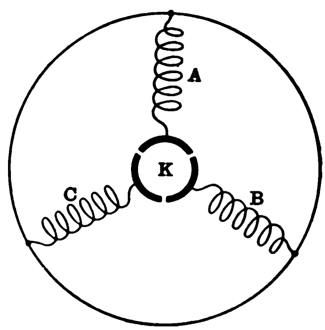


FIG. 87.—DIAGRAM OF ARMATURE CONNECTIONS OF ECLIPSE METER.

drop on a meter of this size is 1·2 volts. The torque, however, varies in different sizes. The shunt current has a constant value of 0·02 ampere, but the ampere turns are varied, being 595 in the 5-ampere size, 650 in the 10-ampere size, 1,000 in the 20-ampere size. The torque of a 20-ampere meter is about 4·7 gramme-cm, the drop being 0·25 volt at full load.

The above figures refer to meters of the B.N.R. type, and are about the same in the N.R. (or double coil) meters. From tests made on 50-ampere meters of this type, the mean full-load torque appears to be about 4·5 gramme-cm. and the drop 0·12 volts. The shunt current is the same, viz., 0·02 ampere.

Two types of brushes are used on these meters. In one, known as the "No. 1 type," two extremely thin strips of

silver are clamped to each of two stout circular brass rods, the latter being supported by the posts seen in Figs. 84 and 85 on the front of the iron plates. These posts are, of course, insulated from the iron plate. The thin silver strips are very flexible, and being clamped at their ends so as to stand out from the rods, they are pressed against the commutator upon which they bear on a small arc. These brushes cause more friction, therefore, than if they simply touched at a point, as they tend to drag, especially if the commutator gets slightly dirty. In practice they have been found to wear and break easily when a slight sparking takes place. The other, or "No. 2 type," are far more satisfactory. The brush is stamped out of comparatively stout metal, and is hinged at the end of similar but shorter brass rods. Each brush at the commutator end is split so as to form two arms, and the arms are twisted, so that contact with the commutator is made on the edge of the metal instead of on the flat. A very fine spiral spring supplies the necessary tension for keeping the brush against the commutator; the required tension being obtained, as with the No. 1 type, by twisting slightly the supporting posts. The illustrations show the meters fitted with cyclometer dials, but they can be obtained with ordinary dials of a very bold form, which, in the Author's opinion, are much to be preferred, owing to the smaller and more constant friction which they introduce, and to their freedom from jamming.

The brake magnets are placed in the position in which they are least affected by the field of the main coil—*i.e.*, with their length at right angles to the field, but the meters are also provided with magnetic screens between the coils and magnets to minimise the effect of short-circuits.

Tests on continuous-current and 60 $\sim$ and 100 $\sim$ alternating-current show no difference in the constants. The meters are also remarkably good on inductive loads. 100-volt meters have been found to be about 0·8 per cent. faster and 200-volt meters 1·2 per cent. on loads the power-factor of which was 0·5 (which is lower than would usually be found in practice) than on non-inductive loads.

The B.N.R. meters are made in sizes from 2·5 to 20 amperes, and the N.R. type in sizes from 2·5 to 75 amperes.

The Mordey-Fricker Meter.—The Mordey-Fricker meter is one which stands apart from others, being of a type quite distinct from any other meter. It is essentially a balance-wheel clock, the escapement being affected by the current to be metered in such a manner as to cause the clock to work at a speed proportional to the current. The meter is therefore an ampere-

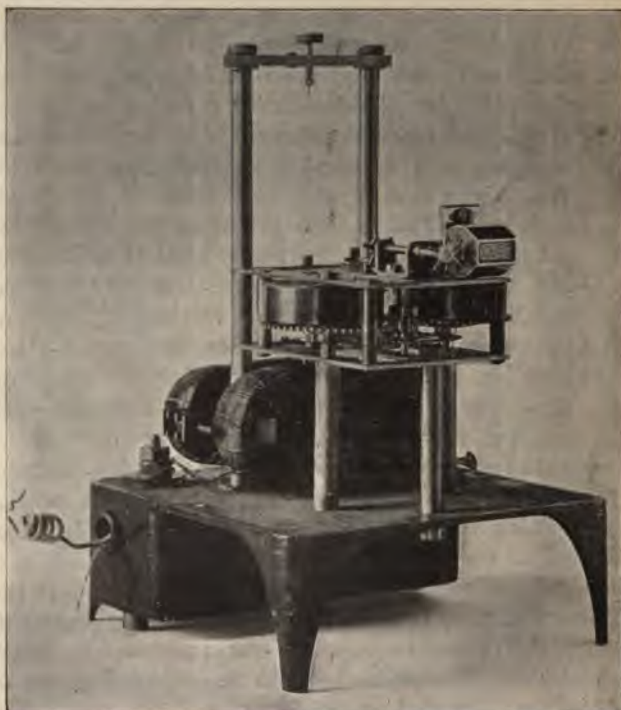


FIG. 88.—MORDEY-FRICKER METER. CASE REMOVED.

hour meter, but is provided with dials geared to the clock train, which indicate Board of Trade units at a given pressure. The clock is worked by two springs, which are hand-wound. A 100-volt four-ampere meter requires to be wound after 80 B.T. units have been passed through it. Thus, if there is a daily consumption not exceeding 0·88 B.T.U., or full load for 2·2 hours per day, it would not be necessary to wind the

meter more than once a quarter. As the clock does not work until current is passed through the coils of the meter, the springs are not unwinding continually.

Figs. 88 and 89 are illustrations showing a meter of this make with cover removed, from which it will be seen that the ordinary balance spindle of the clock is replaced by a longer one, carrying, in addition to the balance wheel, a disc situated

FIG. 89.—ANOTHER VIEW OF MORDEY-FRICKER METER.

in the field of two coils. In the figures the main spindle is shown supported by a tortionless silk thread attached to the spindle by a bent wire spring, thus relieving the jewel of the bulk of the weight. This method of suspension has, however, been discarded, and an ordinary upper bearing replaces the thread. The disc is of slate, and has a few pieces of iron wire let into grooves cut in its upper surface in such a direction that

the iron wires are at right angles to the planes of the coils when the disc is in the mid position of its oscillation. Fig. 90 gives an idea of the balance wheel spindle or main moving part of this meter. In this figure, A represents the top bearing, B the balance wheel, S the slate disc showing the grooves containing the iron wires, L the lever pin, and J the footstep jewel.

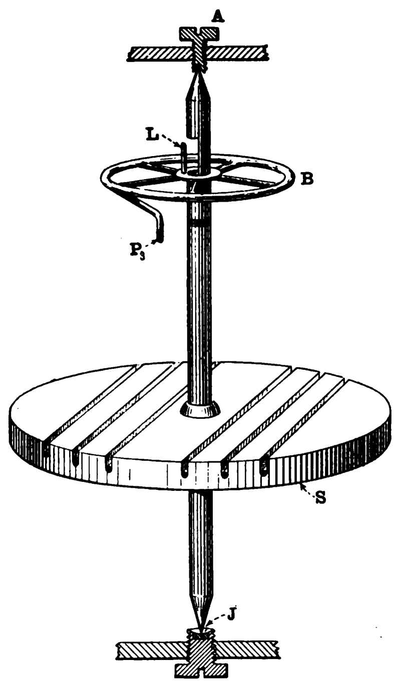


FIG. 90.—SKETCH OF BALANCE-WHEEL SPINDLE.

The pallets are shaped so as to induce the disc not to stop in the midway position when at rest—that is to say, when no current is passing the disc is caused to remain stationary at one end of its beat. Upon this point depends the successful working of the meter. If from any cause, such as increased friction or the mainspring becoming weak, the disc stops in a midway position, the meter does not register when a current passes.

The principle of action is as follows:—When a current flows through the coils the iron wires embedded in the disc are acted on by the field of the coils, and they therefore try to take up a position parallel to this field. The momentum of the disc and the force exerted by the main spring through the pallets cause the disc to turn further, and thus the oscillation of the disc is kept up by the combined action of the clock and the force exerted on the iron in the disc by the field. When the current ceases to flow, the directive force acting on the iron in the disc ceases, and in consequence the disc remains stationary. As the force exerted by the field is altered by the strength of the current varying according to the load, so the period of oscillation is altered, the amplitude also becoming smaller as the field increases in strength. When, therefore, the current becomes strong enough, it overpowers the force exerted by the main spring, and the disc, being held up in the central position of its oscillation, the meter stops until the current is switched off. This, however, does not happen until the meter is considerably overloaded.

The law of the meter would be a straight-line one if the amplitude of oscillation remained constant under varying loads, and if no extraneous accelerating force was derived from the main spring through the pallets. As a matter of fact, the amplitude is considerably shortened on the higher loads, and the impulse given in the middle of each swing by the action of the pallet constitutes an accelerating force independent of the load. These two disturbing elements tend to some extent to counteract each other—*i.e.*, when the current is small and the amplitude wide the constant acceleration due to the pallet impulse is an important factor in maintaining the rate of oscillation, which would otherwise be too slow owing to the increased amplitude. On the other hand, at high loads the pallet impulse is negligible as compared to the strong magnetic force.

In spite of these counterbalancing effects, a further controlling device is necessary, as in practice there is a great tendency at very low loads for the amplitude to increase so much as to strike any fixed limiting stops or banking pins with sufficient force to cause a rebound, and so to set up an independent cumulative accelerating force. To avoid this the device shown

in plan in Fig. 91 is introduced. The movable stop plate A is pivoted at N to a portion of the clock-frame B, but as it lies on B it possesses friction when moved. S is the main spindle carrying the balance-wheel and slate disc. The plate A is capable of moving about N between the banking pins P1, P2. The pin P3 (see also Fig. 90) is rigidly fixed to the balance-wheel, and at the end of each oscillation strikes up against the plate A, the friction of which, as it slides on the clock-frame B, not only takes up any unexpended energy in the balance, obviating a cumulative rebound, but also serves to limit the angular excursion of the balance.

When one lamp only is switched on, the directive force due to the main coils is very feeble, and the pallets tend to drive the oscillating portion too quickly. To prevent this the banking gear is modified as in Fig. 92, where similar letters

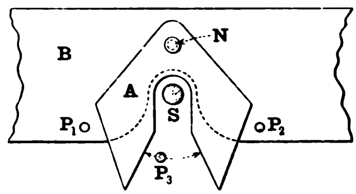


FIG. 91.

indicate the same parts as in Fig. 91. It will be seen that one side of the banking plate A is cut away so as to form a step. This plate, instead of being on the clockwork frame, is mounted on a brass bar D, which is pivoted at M and carries at its end the core C of a solenoid.

The bar D is capable of moving between the stops P4 and P5, being held normally against P5 by a small spiral spring Sp. The main current passes through the solenoid, and the spiral spring Sp is so adjusted that it overcomes the pull on the core when the current taken by only one lamp passes through the coil; consequently for the first lamp switched on the travel of P3 is in the widened gap in the plate A. On two or more lamps being switched on, the core C is pulled into the solenoid, causing D to come up against P4 and shifting A towards P3, so that the banking takes place in the shorter gap.

The meters are now provided with an ordinary counting train in place of the one shown in the illustrations. As one revolution of the dial hand is equivalent to 0·1 B.T.U., the meter can be easily tested by passing a steady current for sufficient time to obtain a reliable reading; or the number of oscillations per unit can be obtained from the wheel ratios and short time tests taken by counting the beats. The meter requires calibrating for the circuit on which it is to run. There is also a slight addition to the continuous-current meter in the shape of a bar magnet, the flux of which opposes that due to the coils.

For lamp loads the meter is only made in small sizes up to 4 amperes.

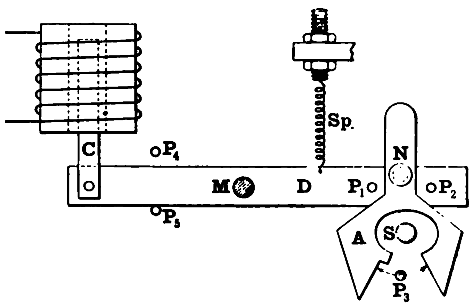


FIG. 92.

The mains enter through bushed holes in a separate chamber or terminal box, the lid of which is underneath and allows of separate sealing.

The Schuckert Meter.—One of these meters is illustrated in Fig. 93. The armature is drum wound and situated in the field of two coils which carry the current to be metered. The meter is notable for its strong design and beautiful finish. The back is of aluminium and supports the main coils, which are circular, the high resistance in series with the armature, and a strong cast aluminium frame. The latter carries the counting train, brake magnets, and main spindle bearings. An iron screen is fixed between the brake magnets and main coils.

The shunt current, after traversing the non-inductive resistance, which is wound on the porcelain bobbin seen at the top

left-hand corner (Fig. 93), enters a compounding coil also seen in the figure, partly inside the left-hand main coil. This compounding coil is mounted on a threaded spindle, and can therefore be shifted towards or away from the armature by small steps, and when finally clamped there is no chance of it altering its position.

The brush gear of this meter is probably the most perfect of any meter. Each brush consists of 10 fine straight silver wires,

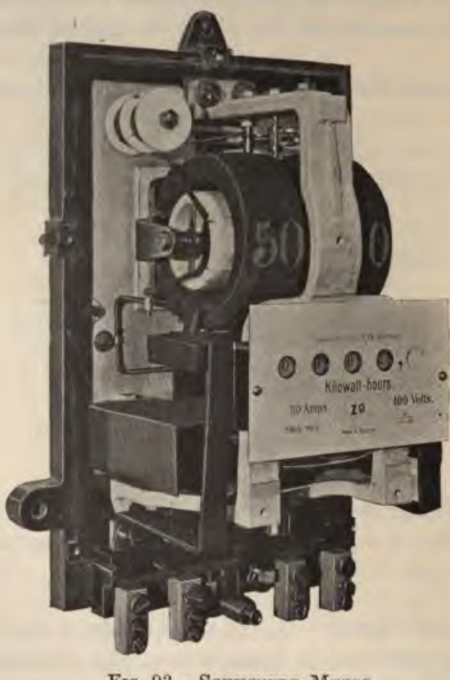


FIG. 93.—SCHUCKERT METER.

3·3 mils in diameter, and about 1in. long. These wires are soldered at one end to a small brass support projecting from a spindle which is delicately pivoted. The inner end of a phosphor-bronze spiral spring is fixed to the spindle, the outer end being soldered to the rigid support. By this means the brush is pressed against the commutator at a very delicate and constant tension and at 10 points of contact. The main moving

portion is shown in Fig. 94. Above the corrugated brake disc a massive worm is clamped on the main spindle, which engages with the worm wheel. The armature consists of a number of coils, which, as will be seen, are not all the same shape, the outside ones being approximately circular whilst the underneath ones are elliptical. Their ends are led up and soldered to the 14-segment commutator just above.

These meters are either provided with ordinary dials or, as shown in Fig. 93, with a special form (which is not of the usual

FIG. 94.—MOVING SYSTEM OF SCHUCKERT METER.

cyclometer pattern), indicating the units consumed in plain figures. The figures in this type of counting train change instantaneously, so avoiding any intermediate reading as is possible with cyclometer dials. The figures are on thin circular plates, which are mounted on spindles and lie alternately one behind the other close to the front plate, appearing to be all in the same plane. The "tenths" wheel travels evenly when driven, and during part of its revolution raises a weight which is held

by a loose sleeve on its spindle. When the weight is raised sufficiently its centre of gravity is shifted to the other side of the spindle, and, being free to fall, it does so quickly, turning a circular disc rigidly fixed to it concentrically with the spindle. The one tooth with which this disc is provided near its periphery comes into gear, as the weight is falling, with one of 10 teeth on the next spindle, so turning the number circle one-tenth of a revolution and bringing another figure into view. These counting trains do not appear to be liable to jam, and the weight is heavy enough to work all the dials at once, with a little to spare. An objection is that they will not work backwards, so that if a meter was connected up wrongly no reading would be produced. When the weight is being lifted, the power required to drive the counting train is slightly increased, but this has been found to make very little difference to the speed of the meter. At as low as three-fiftieths of full load the difference in the speed obtained between results taken during lifting and when the lifting is not being performed only amounted to 1 per cent., and would, of course, be less at higher loads. The shunt current is about 0·025 ampere and the main circuit loss about the normal. The full-load torque is low for this class of meter, being about 5·5 gramme cm. The torque is not constant throughout the revolution, probably owing to the different areas enclosed by the armature coils, and this affects the starting current and very low-load speeds. The weight of the moving system is about 250 grammes. A substantial cover, the rim of which beds on a velvet ribbon stuck on the back plate, makes a good dust-tight protection to the meter, and a separate cover fits over the terminals. The internal connections are such that they require both mains to be cut and taken into the meter, which means that they are what in other makes would be called "three-wire" meters. The very convenient clamping gear, which is operated by simply giving a screw two or three turns one way or the other, made definite by stops, is worked through a hole in the cover, the latter being closed by the terminal box.

The Thomson Meter.—One of the oldest and most used meters is that due to Prof. Elihu Thomson. It consists of a motor without iron—the field being excited by the main current, a

shunt current passing through the armature—combined with a Foucault brake. Fig. 95 illustrates a meter of this make, its cover and one of the main coils having been removed to give a better view of the armature, commutator and brushes. The meter is here seen mounted on a testing stand. The armature consists of eight coils of fine silk-covered copper wire wound on a light octagonal frame. Each coil has about 800 turns, and a resistance of about 320 ohms, giving a total resistance of

FIG. 95.—THOMSON WATT-HOUR METER. COVER AND LEFT-HAND MAIN COIL REMOVED.

2,560 ohms, or a resistance from brush to brush of approximately 640 ohms, the armature being drum-wound. The wiring of this armature is shown in Fig. 96, or developed in Fig. 97, from which it will be seen that the ends of the coils are connected to an eight-part commutator of small diameter (0·25in), the segments of which are of silver. The armature is fixed on the spindle in the older types by two clamping screws in the centre.

These screws can be got at by means of a small wire driver between two of the coils. The later armatures, however, are clamped to the spindle by a split cone underneath the armature, which is threaded and clamped tight by a nut.

The commutator is mounted on the vertical main spindle, immediately over the armature, and two brushes, supported by an insulated brush bracket, convey the current to and from the commutator. The brushes are made of thin straight springs, having small plates of silver soldered on their ends, where they make contact with the commutator segments.

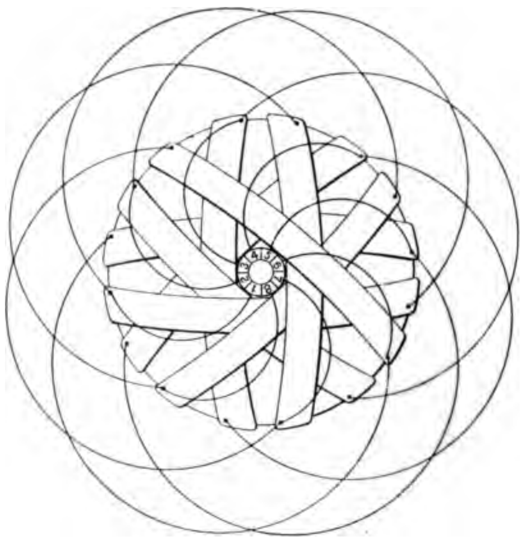


FIG. 96.—WINDING OF THOMSON METER ARMATURE.

The armature is connected in series with a non-inductive resistance (wound in sections on a card placed at the back of the meter), and a compounding coil across the two supply mains, consequently the current in it is proportional to the pressure. The main current is passed through two stationary hollow main coils, placed on either side of the main spindle, so that the armature is in the field produced by the current through them. A torque is therefore obtained proportional to the watts. A copper disc mounted on

the lower portion of the main spindle runs between the poles of two permanent magnets, and thus the necessary brake force is produced. A polished steel pivot is screwed into the bottom of the main spindle and rests on a spring-seated jewel. This spindle point is easily removed for repolishing by means of a key. The jewel-screw being removed, the key is inserted in the hole in the bell-nut. The top of the spindle is turned to a small diameter and runs in a brass bearing. Just below this bearing a worm is turned on the spindle which works the counting train. The mechanical friction due to bearings, brushes and wheel train is relatively large, but is kept as low as possible. This friction is compensated for to a certain extent by creating a permanent field in the same direction as that due to the current in the main coils, by passing the shunt current through a compounding coil placed inside of the main coils.

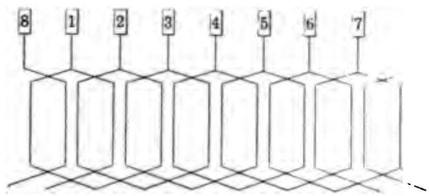


FIG. 97.—WINDING OF THOMSON METER ARMATURE DEVELOPED.

The compensation should not be complete, as the meter would then "creep," or register with no main current when installed where it would be subjected to slight vibration, such as that due to passing traffic. The compounding coil is wedged in the main coil, and a slight amount of adjustment can be made by altering its position. The amount of alteration which can be made in this way is about 4 per cent. at one-tenth load. The tension of the brushes has more effect, however, but it is not advisable to leave them on too light, otherwise sparking will take place, which soon increases the friction. The tension should be such that on raising one half of a brush off the commutator the other half leaves the commutator when the first half is about $\frac{1}{16}$in. away. Another important point is that each brush presses quite flat, and not on an edge, on the commutator. The successful working of this meter, and indeed of

all commutator meters, depends to a great extent on the careful adjustment of the brushes.

Beneath the case proper a terminal box is fixed, shown in Fig. 95 with its cover removed. The mains are taken through holes in the bottom, opposite holes in the terminals. The terminal-box cover fits on the front of the box, and is held in position by a brass rod which is slid through the holes in two lugs, one at each side of the terminal box. This rod has a small hole through it at one end, through which the sealing wire is passed. The other end of the rod is enlarged to prevent it passing through the hole.

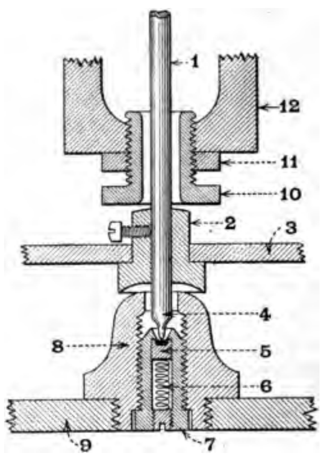


FIG. 98.—ARRANGEMENT OF CLAMPING GEAR AND LOWER BEARING OF THOMSON METER.

The meter is clamped or unclamped by removing the jewel-screw and raising or lowering the bell-nut which screws into the base-plate of the meter. Raising this bell-nut (by means of a screwdriver of the right width) lifts the hub of the copper disc until its upper side comes in contact with the hollow stop-screw above it. The jewel-screw is then replaced, but not screwed home. The arrangement is shown in section in Fig. 98, where 1 is the main spindle on which is clamped the hub 2 of the disc 3; 4 is the removable spindle point, 5 the mounted jewel resting on spring 6 in jewel-screw 7, which

screws into the bell-nut 8, the latter screwing into the base-plate 9 of the meter. The hub 2, when raised by the bell-nut 8, comes up against the adjustable screw 10, which screws into the frame 12. This screw is correctly adjusted when the meter is assembled and locked by the nut 11. The screw 10 should be low enough, or the top bearing high enough, to prevent the spindle being jammed up against the top bearing, as a risk is then run of bending the spindle at the worm.

The terminal-box cover has a lug which covers up the hole in the meter base through which the clamping is performed.

The meter possesses a very high torque; the full-load torque from numerous measurements appears to vary slightly in different meters, but is usually between 25 and 30 gramme-centimetres. The weight of the moving system is approximately 300 grammes, being one of the heaviest in any meter, but the high torque obtained is greatly in its favour. The friction being in a great measure compensated for, the ratio of torque to frictional counter-torque (that which is not compensated) is very high. The shunt current varies in different sizes slightly, being about 0·03 ampere in sizes under 50 ampere capacity, and from 0·04 to 0·05 ampere in the larger sizes.

The meter is adjusted by altering the position of the brake magnets, they causing maximum drag when near the rim of the disc, but with their poles completely covering it. They are clamped to the base by two screws, the screws passing through slotted holes to enable the magnets to be shifted. The low-load adjustment is made either by shifting the compounding coil, or by alteration of the friction by varying the tension of the brushes. If, however, the brushes are altered, it is advisable to test the meter again at full-load to make sure that no sparking takes place.

The cover is not dust-tight, but veterinary vaseline placed round the join of cover and case makes a practically dust-tight joint.

The Thomson meter is equally suitable for use on continuous or alternating-current without mechanical alteration, but in the 5-ampere and 50-ampere and upwards sizes it should be tested on the current on which it will be required to work, as a difference of about 3 per cent. will be found—the meter

being slower on alternating current on the larger-sized meters, owing to the ratio of the resistance to the self-induction being slightly decreased, these meters having lower "non-inductive" resistances. The meter is slightly faster on inductive loads; the difference is not, however, large. From tests made, a 100-volt 50-ampere meter was found to be 3·2 per cent., and a 100-volt 75-ampere meter 5 per cent. faster on an inductive load of power-factor = 0·47.

The British Thomson-Houston Co. have recently introduced a new type of the Thomson meter, known as the A

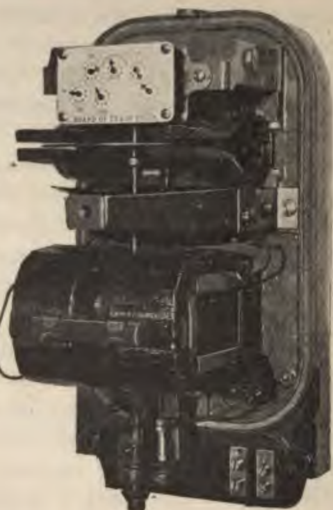


FIG. 99.—THOMSON TYPE A WATT-HOUR METER WITH COVER REMOVED.

type. A view of this meter, with its cover off, is seen in Fig. 99. It will be noticed that several alterations have been made. The brake magnets and disc are placed above the motor, whereas the commutator is in a much better situation at the bottom end of the spindle. Here it is not so subject to vibration as when it is just under the top bearing. The brushes consist of spring wires having silver ends, and they are supported by two posts clamped to an insulating block held in a cast support. The cover of the meter is dust-tight, bedding

all round in a felt-lined groove. It is fixed by only one thumb-screw which screws into the brass band seen between the brake magnets and the field coils. A hole in the bottom of this cover allows the brush gear to pass through it, enabling the jewel and commutator to be inspected without breaking the main cover seal. A dome, similar to that of the O.K. meter, covers up this gear and is sealed at the same time as the terminal cover.

The clamping is also much simpler than in the old type meter. The jewel-screw is threaded at both ends, having a milled head in the centre, and a jewel at one end only. To clamp or unclamp the meter, all that is necessary, therefore, is to turn the jewel-screw upside down and screw it home in the hole provided for it in the same casting as supports the brush bracket.

In the smaller sizes tenths and hundredths hands are provided for short dial-reading tests.

A wooden distance-piece is fixed to the front of the main coils, as seen in Fig. 99. This prevents all chance of a bad short-circuit bringing the coils together, which might otherwise happen, owing to the great force of attraction which is produced by the abnormal rise in current which may take place on such an occasion. The torque of the meter has unfortunately been reduced, which is a step in the wrong direction. From measurements made on meters of this type it appears that the full-load torque is about 10 gr. cms. in meters of the usual sizes. In very large sizes the torque is more, being about 14·5 gramme-cm. in 200-volt 300-ampere meters. The weight of the moving system is slightly less than in the older type meter, being about 263 grammes, but the torque per gramme weight of moving system is much less in the new type meter, the figures being: Old type, 0·084; new type, 0·039.

The Vulcan Meter.—The Vulcan meter is similar in principle to the Thomson meter just described; there are, however, certain points in which it differs from that meter. Fig. 100 shows a house-type meter of Vulcan make with its cover off, but a better idea of the general arrangement may be obtained from the side-sectional view, Fig. 101. The main current

passes through two main coils, A, so wound as to have about 1,200 ampere-turns at full-load.

An armature, B, which is very similar to that of the Thomson meter, has a total of 6,400 turns of 1mm. silk-covered copper wire wound in eight coils of 800 turns each. It is drum-wound, the resistance from brush to brush being 620 ohms, and at a shunt current of 0·02 amperes has a

Fig. 100.—House Type Vulcan Meter. Cover removed.

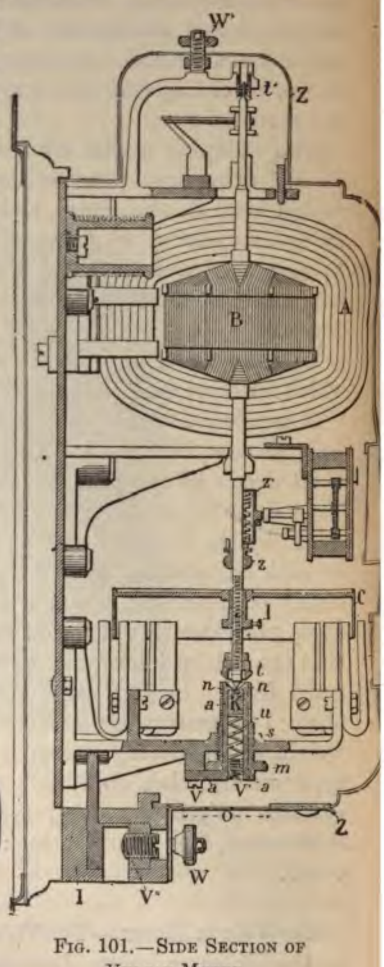
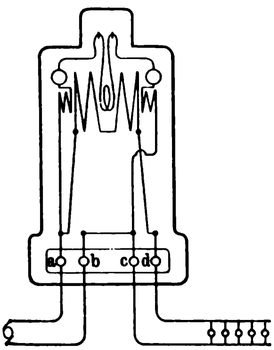


Fig. 101.—Side Section of Vulcan Meter.

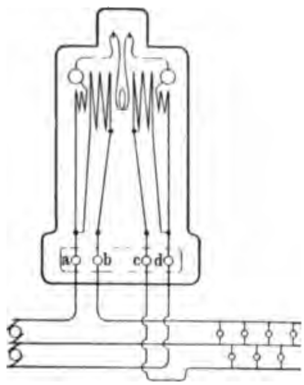
drop of 12·4 volts. The copper ring C, which replaces the usual disc, runs between the poles of eight magnets, M. The number of magnets has now been reduced to four, these being of better

design for permanently retaining their magnetism. The hub of the copper ring is screwed, and can be run up or down the threaded portion of the main spindle, being clamped by the screw I. This makes adjustment of the meter very convenient, as it enables the copper ring to be lowered into the field of the magnets by any small amount when near the desired position.

The main spindle, which has a removable pivot underneath it, runs on a jewelled bearing K, the jewel being spring-supported. The main spindle is raised off the jewel by screwing *m*, which causes the collar *n* to rise and lift *t*. A hole, O, in the cover enables this to be done without removing it. O is closed by the terminal-box cover, the latter being



2-Wire.



3-Wire.

FIG. 102.—VULCAN METER CONNECTIONS.

held on by the milled nut W. The worm and worm-wheel are missing, the motion of the main spindle being transmitted to the wheel train by the wire pinion Z, and the crown-wheel Z^1. A dome at the top, which is separate from the main cover, enables the brushes and commutator to be examined without removing the main cover.

The commutator, the diameter of which is 0·24in., is situated just below the top bearing, and the current is conveyed to and from it by wire brushes. Each brush consists of five straight silver wires, soldered at one end to a thin piece of springy metal. The wires themselves possess a slight amount of spring and bear on the commutator near their free ends.

Each wire is to a certain extent independent of the others, but as they lie close to one another the independence is not so permanent as it would be if they were separated, for if one brush is lifted off the commutator by a speck of dust it tends to pull those next to it with it. When separated they have been found to work much more satisfactorily.

The connections for two and three-wire meters are shown diagrammatically in Fig. 102, *a*, *b*, *c*, *d* being the four binding

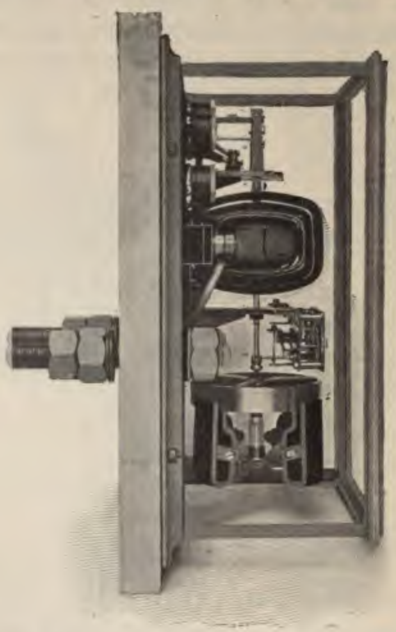


Fig. 103.—Vulcan Switchboard Meter. Side View.

posts. In the two-wire meter it is, of course, not essential that the lower main be cut and both ends taken into the meter, a tee taken to either of the middle terminals being sufficient, and will in some cases be found more convenient.

For switchboard use these meters are made in sizes from 10 to 2,500 amperes. Fig. 103 is a side view of a 200-ampere two-wire meter of the switchboard type, fitted with the newer type magnets already referred to.

The shunt current is uniform in all sizes, and is approximately 0·02 ampere. The necessary high resistance in circuit with the armature is wound double on porcelain bobbins, each bobbin having about 2,000 ohms and a drop of 40 volts. The capacity of these bobbins slightly overbalances the self-induction of the armature, causing the meter to slightly under-register on inductive loads. The balance, however, is nearly correct, as the difference in the constant is about 1·7 per cent., between a unity and a 0·47 power-factor-load. There is practically no difference in the constant on non-inductive alternating and continuous-current circuits.

The full-load torque is low, being roughly 8 gramme-cm. The weight of the main moving part is 230 grammes.

CHAPTER V.

PREPAYMENT METERS.

Of late years the prepayment meter has come very much to the front, and is being used extensively. The introduction of this class of meter, in conjunction with free-wiring schemes, has practically opened fresh fields for the supply and consumption of electrical energy by facilitating its introduction into the smallest class of dwelling. The small consumer, owing to the fact that he uses a greater percentage of his installation, and uses it more regularly, than does the very large householder, whose house is shut up for a great part of the year, creates a better load-factor for the station. The use of prepayment meters also simplifies accounts considerably, more particularly in those cases where the tenants are constantly changing; for possibly two or three accounts might have to be sent out per quarter, to say nothing about the difficulty on occasions of finding the "leaving" consumer. The scope of the prepayment meter is, however, not confined to the poor man's dwelling. Its use in flats is gradually becoming more extended, and in furnished apartments, where the consumers are chiefly nomadic, it relieves the proprietor of all responsibility as regards the consumption, over which he has practically no control.

The prepayment meter is, generally speaking, a much more complicated piece of apparatus than the ordinary meter. In most cases the prepayment mechanism, which necessarily includes an automatic switch, is an addition to such a meter, but in others the meter is only made in the prepayment type. The addition necessary to convert an ordinary meter into the

prepayment type increases the price of the apparatus, and, taking into account that small meters are relatively more expensive than large ones, and also that the prepayment system is restricted to the smaller sizes, it is obvious that the capital outlay on meters is increased by the adoption of the system. It is of the highest importance that the prepayment mechanism be absolutely reliable, and to be so it must be well made. The fact that the consumer may be left without light, owing to some defect arising in the meter, would not tend to increase the popularity of the system. Changing defective meters, and the cost of remedying their defects, if frequent, would soon make a low-price meter dearer than a better made and more expensive meter, even of the same make.

The prepayment mechanism has much to contend with. It has to be proof against being tampered with. It must be capable of working with coins of varying thickness, *i.e.*, with new or fairly worn ones. It should also allow of several coins being inserted in rotation at a time, as probably most consumers would prefer to put more than one in, and so avoid frequent visits to the meter and the chance of having the light cut off at an inopportune moment. There should, moreover, be no chance of the switch cutting off before the correct time, or of its remaining closed after the energy paid for has been consumed.

The operations which the consumer has to perform must be extremely simple, and if these operations are not performed in the correct order, it should in no way disturb the adjustment of the mechanism. In addition to showing the number of coins inserted (as a check on the collector), the meter should be provided with an indicator showing the amount prepaid, and giving some intimation of the fact that it is necessary to insert more coins to prevent the current being cut off. A set of dials may also be included, showing the number of Board of Trade units consumed, but this is not absolutely necessary. The rate per unit should be capable of being easily changed, for it may be that the same undertaking may supply at two different rates; for instance, a high rate in the case of free-wiring jobs, and a lower rate where the free-wiring scheme has not been taken advantage of. The easy changing of the rate of charging is, however, essential, even if no free-wiring scheme has been

adopted, as it is very possible that the price per unit may be reduced from time to time.

For the poorest class of consumer the "penny in the slot" meter is the most popular, and as the meters would rarely be larger than 2-ampere capacity on 100-volt supply, or 1 ampere on 200-volt supply, the penny meter is quite suitable. At 6d. a unit, 167 watt-hours are obtained for 1d., consequently three 8 c.p. lamps could be kept on for approximately 1¾ hours. In the larger sizes the silver coin meters are much to be preferred, owing to the less frequent visits to the meter they require the consumer to make, and to the greater ease with which the money is collected and checked against the indication given by the meter dials of the amount which ought to be found in the till.

The British Thomson-Houston Prepayment Meters.—The British Thomson-Houston Co. manufacture two types of prepayment meter, the one being suitable for alternating-current circuits and the other for continuous-current circuits. The prepayment mechanism is identical in both types, and although one specially-designed cast-aluminium case contains the whole apparatus, the prepayment mechanism is really an addition to a meter of the A.C.T. type (see Chap. II., p. 42) for alternating-current circuits, or to one of the O.K. type (*see* Chap. III., p. 79) for continuous-current circuits.

The external appearance of the continuous-current prepayment meter is seen in Fig. 104, whilst Fig. 105 illustrates an alternating-current meter with its cover off, and the coin shoot A and till B removed, to give a better view of the prepayment mechanism. The slot to receive the coins is on the upper left-hand side, being cut in a direction plate on the front cover of the meter. The coin being inserted, a handle on the left-hand side of the meter is raised to the top stop and lowered again. This action, with the first coin inserted, causes the pointer (seen on the left-hand side of the dial plate) to move one division on the scale, and then closes the switch *c* (Fig. 105). This scale indicates "coins unconsumed," and the pointer is worked by a differential gear, it being raised one division by each coin inserted, and gradually brought back to zero by the motion of the wheel train, which is actuated by the meter.

FIG. 104.—B.T.H. CONTINUOUS-CURRENT PREPAYMENT METER.

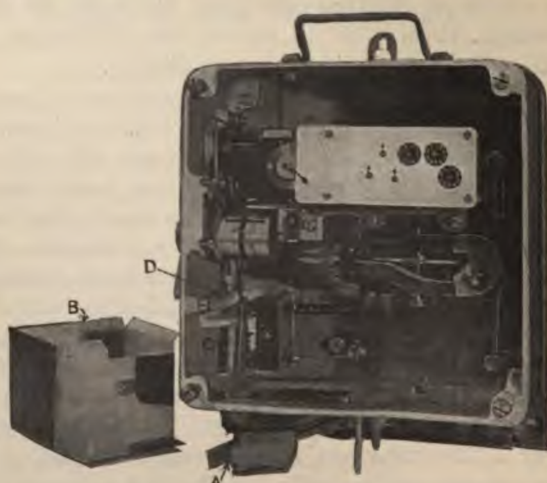


FIG. 105.—B.T.H. ALTERNATING-CURRENT PREPAYMENT METER. COVER, TILL AND COIN SLOT REMOVED.

As many as 10 coins may be inserted at a time. The switch-arm is pivoted at its upper end, and a strong helical spring, D, constantly tends to pull it off. A hook, pivoted to the case at the back, engages with a pin on a lever on the switch-arm, and holds the latter on against the tension of the spring so long as the pin-carrying lever is held by a second lever or catch. The front end of this second lever is prevented from dropping by a circular disc containing a gap in its periphery, which is turned backwards and forwards. This disc is turned in the one direction by action of the coin on a lever carrying a ratchet, and in

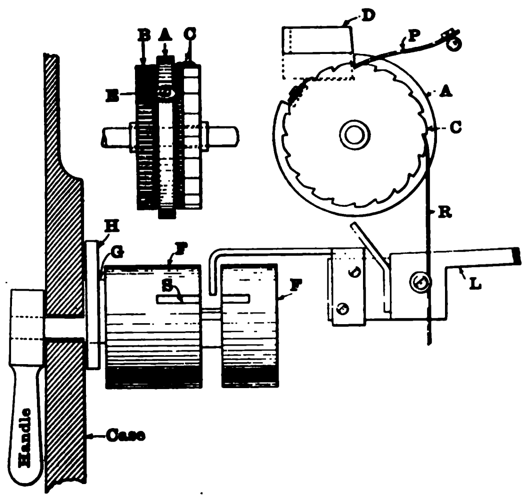


FIG. 106.—B.T.H. METER. PART OF PREPAYMENT GEAR.

the reverse direction by the action of current. The switch is of the single-pole quick-break knife type and is positive in action.

The differential gear is seen in Fig. 106, and consists of three concentric wheels; the middle wheel, A, of the three is fixed to the spindle on which the two outer ones, B and C, are loose. The latter are toothed wheels, each having the same number of teeth. To the front wheel C a disc, having 20 teeth or notches, is fixed concentrically, and a ratchet, R, mounted on a lever, L, which is raised by the coins, turns this disc and front toothed wheel one-twentieth of a revolution per coin. A spring pawl, P, fixed to the upper left-hand pillar of the wheel

train frame, holds A in position. The other toothed wheel, B, at the back, is in gear through a train of change wheels with the units spindle of the recording dials. The change-wheel ratios are so designed as to cause the back toothed wheel of the differential gear to turn the required amount in the opposite direction to the front wheel. The wheel A, between the two toothed wheels, has a plain rim, except at one point, where it is cut away. When there are any coins prepaid, the rim of this wheel prevents the front end of a lever, D, falling, which, when held up, holds the switch on; but, on the wheel A being turned by the clock train until the part cut away comes underneath D (this allowing D to fall), the switch is at once released and the light cut off. This happens when the amount prepaid has been consumed. The middle wheel A, having a planet wheel, E, on its periphery, which engages with both the outside toothed wheels, is turned in one direction by the front wheel and in the other by the back wheel. It is always turned one-twentieth of a revolution per coin in the one direction, and the amount it is turned per unit consumed in the opposite direction by the back wheel depends on the ratio of the change wheels, which is decided by the price to be charged per unit.

For example, if the price to be charged is 6d. per unit, and the meter is designed to take sixpenny pieces, then, as the coin will turn the middle wheel one-twentieth of a revolution, the change-wheel ratio must be such that one division on the units dial, *i.e.*, one Board of Trade unit, will also turn the middle wheel one-twentieth of a revolution back. The position of the middle wheel at starting being such that the arm can just fall in the gap, it is obvious that, since this wheel is turned indirectly by the coin, and turned back again by the same amount by the main moving part of the meter, the switch will be cut off when one unit has passed through the meter. The accuracy with which *each* cut off takes place will depend on the equal spacing of the 20 notches, but, as this wheel always moves in the same direction, after the insertion of 20 coins it will have completed a revolution, so that any inequality will have been compensated. Thus the accuracy of the meter is in no way impaired by the addition of the prepayment gear, for the friction of the arm which presses on the

rim of the middle wheel of the differential gear, and so holds the switch closed, is so far up the train that it is practically not felt at the main spindle. If n coins are inserted at the same time the middle wheel will be turned $n/20$ths of a revolution, so that n units would pass through the meter before the gap returns to its original position, allowing the switch to break the circuit. The work performed by the coin is simply to raise the lever L; the coin falls into a slot S, in a barrel F, which is turned by the outside handle. After raising the lever, further turning of the barrel allows the coin to fall out of the slot into the till, the switch being turned on at the same time by an eccentric G and eccentric strap H.

The continuous-current meter differs very slightly in external appearance; the main difference is the addition of a dome underneath to allow of clamping and inspection of the commutator and brushes without opening the main cover, which is fixed to the main case by four sealing screws and sealed in the test room. The dome is separately sealed at the same time as the terminal cover, and the latter, covering the bottom fixing screws, prevents the meter being taken down without breaking this seal. A hinged door in the base forms the bottom of the till and is usually fastened by a padlock.

These meters are made in 2, 3, 5 and 10 ampere sizes for various voltages and are of medium size, being about $8\frac{1}{4}$ in. × $10\frac{1}{2}$ in. × 5 in. deep.

In the earlier meters of this make the arm of the lever which rests on the periphery of the middle differential wheel and indirectly holds the switch on, was weak, and has in practice been found to bend and so release the switch before it ought to have done so. This arm is now made much stouter, and the spindle on which it rocks is further supported by a bracket from the top of the case (inside). The eccentric strap formerly made of brass gave some trouble by opening out. It is now made of steel. With these improvements the meters are working very satisfactorily.

The Electrical Company's Prepayment Meters.—These prepayment meters consist either of a meter of the R.A. type for continuous-current (*see* Chap. III., p. 59) or of one of the K.J. type for alternating current (*see* Chap. II., p. 32

circuits, together with a prepayment mechanism. A continuous-current or R.A. type prepayment meter, with its cover off, is illustrated in Fig. 107. The prepayment mechanism seen to the right is mounted on a separate back plate, the left-hand side of which forms an arc of the same radius as the meter back-plate, against the rim of which it butts, and is held by screws AA. One cover encloses the whole apparatus, leaving the handle B outside on the right and the terminal box C outside on the left. The meter illustrated is

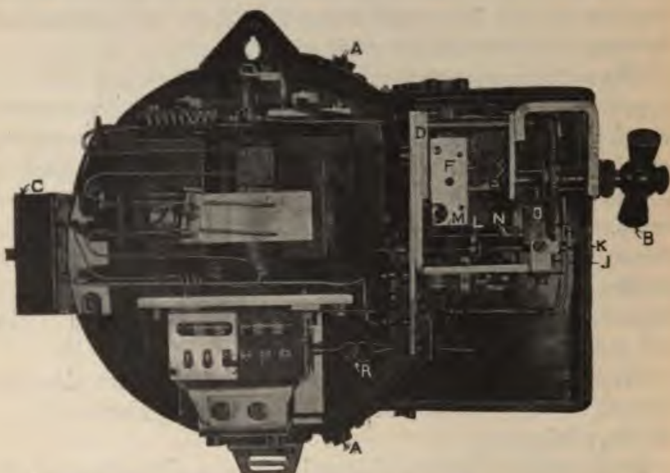


FIG. 107.—ELECTRICAL CO.'S CONTINUOUS-CURRENT PREPAYMENT METER. COVER REMOVED.

designed to take penny coins, and a penny has been inserted through the slot in the top of the case, and is seen in the receiver. The only portion of the work which the coin has to perform is to press back a stop-pin, which is supported on a piece of spring metal, and passes through a hole in the frame D; the pressing back of this pin by the coin allows the shaft E carrying the plate F to be turned by the handle B. With no coin in the receiver the stop-pin prevents the plate F being turned. Further turning, to the extent of about half a revolution of E, closes the switch, credits the consumer with one pennyworth of current, and allows the coin to fall out of the

receiver by gravity into the till, which passes up through the bottom of the cover in a position immediately under the receiver. The shaft E carries a cog wheel, H, which gears with the pinion J, the latter being loose on the spindle K. This spindle is screwed as seen, and upon the screwed portion a nut, L, having a flange of relatively large diameter, is capable of running freely up and down the screw between two stops, M, N, fixed on a rod, which is carried by two flexible supports in such a manner as to allow the rod to be moved slightly along its axis when the flanged nut L engages with either stop M or N. The flexible supports of this rod, by their spring, tend to push the rod and stops to the right. The right-hand flexible support is bent over and cut away to form a catch for a lever, which is pulled towards the front of the meter by a spring, and is pushed towards the back of the meter by a pin, O (driven into the shaft E), when the handle is turned.

The switch arm consists of a plate of insulating material pivoted at the top and carrying a copper connecting piece which makes contact between two blocks—thus completing the circuit—when the insulating arm is pressed down by the lever referred to above, against the tension of a spring which tends to pull the switch off. The lever—being held by the catch in the right hand flexible support of the rod which carries M and N—thus holds the switch on until the catch is released.

The pinion J, which is loose on the spindle K, has a long pin P, which runs parallel to the spindle K fixed to it, as shown in Fig. 108. This pin passes loosely through a hole in the flange of L; thus it will be easily seen that on turning the pinion J (by means of the handle) L is also turned and travels to the right along the threaded spindle. The pinion Q, Fig. 108, being rigidly fixed on to the spindle K and connected through gearing to the main spindle of the meter, turns K when current passes, thus causing L to travel back to its original position, the pin P now acting as a guide, and preventing L turning with the spindle. Returning to Fig. 107 the normal position of L is up against the stop M, by pressing against which the catch holding the lever, which in turn presses the switch on, is released, thus opening the circuit. Each coin inserted with the corresponding turn given to the handle B causes L to travel a definite distance towards N, against which

it eventually presses if sufficient coins (about 10) are inserted. When this happens, the left-hand flexible support of the rod carrying M and N is pulled to the right, which causes a catch to engage with F, so preventing further turning of the spindle E and the insertion of more coins.

The handle B is connected to the shaft E by means of a ratchet coupling, in order to allow a spring lever to cause the shaft E to complete its revolution and to cause F to return to the proper position to receive a coin.

The meter train proper is connected to a second train by the coupling R (Fig. 107), and thus the necessary turning of the screwed spindle K is made proportional to the ampere-hours taken. The price per unit is easily altered by intro-

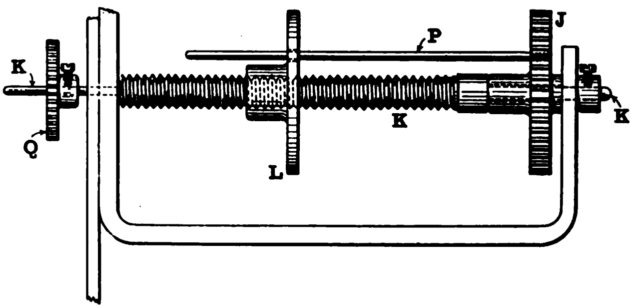


FIG. 108.—DIFFERENTIAL GEAR OF ELECTRICAL CO.'S PREPAYMENT METER.

ducing change wheels into the second train. A scale showing the number of pence prepaid is placed in front of the travelling nut L, the flange of this nut being used as an indicator, it being seen through a horizontal slit in the scale. The cover is provided with a small window immediately in front of this scale.

The prepayment mechanism, although not likely to get out of order easily if properly used, is somewhat delicate, and would not stand rough usage. For instance, if a consumer, not noticing that the maximum number of coins had been inserted, put another in and tried to force the turning, he might in all probability damage the mechanism.

Devices, which prevent the insertion of the coin after this point, are much to be preferred to those which allow the coin to enter, but prevent it being used.

The Hookham Prepayment Meter.—With a view to the elimination of troubles due to bent coins and coins of varying thickness, in the Hookham prepayment meter the coin is simply used as a key or link to raise a catch and allow a lever to turn far enough to release a disc or ball which is used to work the mechanism. These discs or balls, as the case may be, being

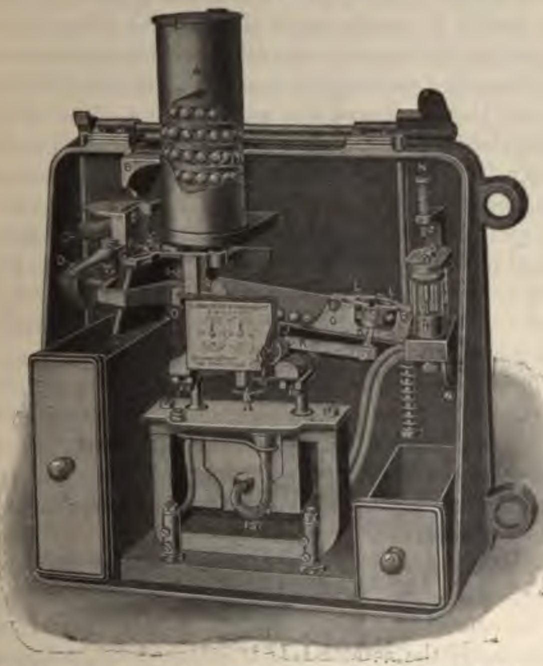


FIG. 109.—HOOKHAM C.C. PREPAYMENT METER. COVER OFF.

made accurately to gauge, are capable of performing their work without the chance of jamming.

A continuous-current meter of this make is shown in Fig. 109, the coin slot B being on top at the left hand. There are two tills or drawers, one at each side, which slide out towards the front. One of these tills is to receive the coins, whilst the other contains the used discs or balls. In the front cover of the meter (removed in the illustration) there is a narrow plate which is screwed to the front between the tills and covers the

terminals. These can thus be got at for the purpose of connecting the meter into circuit without opening the main case.

The reservoir A, partially cut away in Fig. 109, contains the unused checks (which in the meter illustrated are balls). On a coin being inserted in the slot B it at once falls into the slot in the lever C, which is pulled against a stop by the spiral spring shown, so that the two slots are in a line. C terminates in a handle, D, which comes through the front of the meter. On moving the handle to the left (which the consumer has to do after inserting the coin), C moves to the right, about an axis through the screw, and the catch E stops it unless the coin is in the slot in C, in which case the latter raises E and allows C to turn further and release one ball from the reservoir. The coin then falls into the shute and into the left-hand till. Until it is quite clear of C the notch F prevents C returning to its normal position and the insertion of further coins. The ball on being released from the reservoir falls into a grooved beam, G, which is pivoted at O. It runs down the groove until stopped by the first screw L fixed on a rocking arm, K.

The weight of the ball on the beam causes the right-hand end of the latter to drop, which plunges the two prongs into the mercury switch H, thus making the circuit. As many as eight coins can be inserted at a time, releasing eight balls, after which a lever, I, is raised preventing the release of further balls or the insertion of more coins until one or more of the balls have been released from the beam by the working of the meter. The balls are released from the beam one at a time by the meter in the following manner:—The rocker K which holds the screws L L is attached by means of a connecting rod to a crank pin, J, carried by one of the wheels on the counting train. Change wheels are inserted in this train so as to allow one complete revolution of the crank to be equivalent in Board of Trade units to the amount to be sold for one coin, and consequently one ball. The screws L L are so adjusted that, when at their highest position, they just allow the ball to pass under them, and the distance between their points is such that they allow only one ball between them. The left screw rising, allows one ball to pass under it, which is caught by the right screw. By the time the latter finally releases the ball the left screw is low enough to catch the next

ball, which is not finally released until another complete revolution of J has taken place. The released balls fall into the right-hand till and are replaced in the reservoir when the money is collected. An adjustable balance weight, P, at the left-hand end of the beam enables the balance to be regulated so that the prongs are out of the mercury when there are no balls on the beam, and the weight of one ball is sufficient to tilt it.

By means of the screw N the beam is clamped and the mercury tubes of the switch closed for transit. N is unscrewed through a hole in the top of the meter, which is closed by the sealing gear. When unclamping, it should be ascertained that the washers which close the mercury chambers do not stick, and thus hold the prongs in the mercury. It is naturally of the greatest importance to the working of the meter that the beam should be perfectly free to swing, and that the mercury tubes of the switch are filled to the correct level, which is the bottom of the clear portions of the glass tubes.

The tills are held in by the spring bolts at the back. These bolts, together with the cover of the reservoir and the cover for the hole above N, are all worked by a rod along the top of the meter to which the hasp for padlocking is rigidly fixed. Different forms of dials are provided. In Fig. 96 the dial train simply indicates the equivalent in £. s. d. of units consumed. The dials provided in another form of meter indicate the Board of Trade units consumed, and the number of coins used and unused. This latter type of dial is much to be preferred, as it enables the consumer to ascertain when more coins are required to keep the light on.

The meter has a rather low torque. From tests made on a 200-volt 5-ampere 60 ~ prepayment meter, it was found to have a full load torque of 0·85 gramme-cm.

It is made in sizes up to 5 amperes for either pennies or shillings. The penny meters are provided with the balls, of which they contain 120. In the shilling meters discs are used, 25 usually being provided. These numbers of cheques therefore enable the consumer to take 20 and 50 units respectively between the collector's visits at 6d. per Board of Trade unit. After these amounts of energy have been taken the supply would be stopped until the checks were replaced in the reservoir. The system of employing checks in this way, while probably

avoiding troubles due to bent coins, possesses the disadvantage of putting a stop on the action of the meter and the supply of current. With the figures given above, a 200-volt $1\frac{1}{2}$-ampere meter for shilling coins would only enable the consumer to use full load for an average of $1\frac{3}{4}$ hours per day if the collection was made quarterly, and of course larger meters would reduce this time in proportion to their capacity. There is the chance also of the collector omitting to replace the checks in the reservoir.

The meter is large and heavy, its dimensions being 1ft. 1in. square by 5in. deep, and its weight 30lb.

The Mordey-Fricker Prepayment Meter.—The Mordey-Fricker prepayment meter practically consists of an ordinary meter of this make (*see* Chap. IV., p. 112) with certain

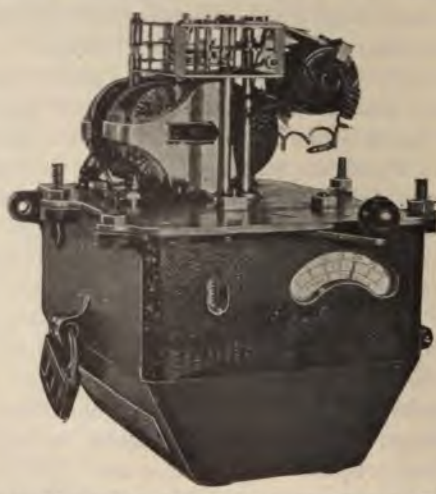


FIG. 110.—MORDEY-FRICKER PREPAYMENT METER. TOP COVER REMOVED.

modifications and additions, and minus the dial train. As will be seen from Fig. 110, a stout brass plate divides the meter into two portions, the meter part proper being above it and the prepayment mechanism, mainspring and switch underneath. The numbers seen through the small window on the left indicate the total number of coins inserted, whilst the pointer and

dial indicate the number of pennyworths still to the credit of the consumer. The bottom case is in two parts, the lower of which (Fig. 110) forms a till. It is hinged on the right and fastened by a padlock passing through two lugs, one of which is on the upper and one on the lower casting. The meter illustrated is fastened with a Tourtel padlock. The mains are passed through bushed holes, one at each side of the upper casting, to terminal posts, these being got at by opening the till. The action consists in the mainspring being wound a definite amount and the circuit made by the consumer, a coin forming a link in what might be termed the winding gear, and the unwinding of the spring and opening of the switch by the working of the meter due to the current passed through it.

Fig. 111 is a view of the underneath portion of a 100-volt 4-ampere meter designed to take sixpenny pieces. The wind-

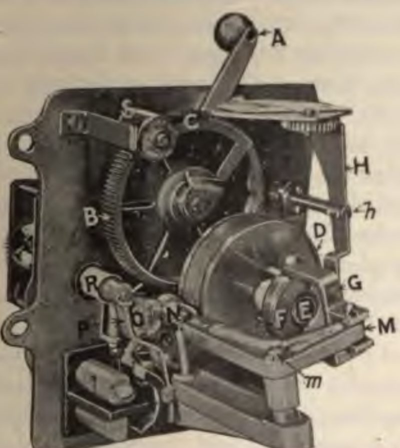


Fig. 111.—View of Mordey-Fricker Prepayment Meter, showing Prepayment Gear.

ing handle A and the large cogwheel B turn about the same axis. The handle turns from its normal position through an angle of just over 60 deg. from right to left, its travel being limited by two stops. A spiral spring pulls it back against the right-hand stop, in which position a slot cut in its arm is directly underneath the coin slot in the brass plate (seen in

Fig. 110). Turning the handle does nothing until a sixpence is inserted. In the wheel B, six radial slots are seen, and one of these is always immediately under the slot in the arm and that in the brass plate. Thus, a sixpence being inserted falls through, and is caught by the brass sector C in such a manner that the coin is partly in the slot in the arm of the handle and partly in one of the slots in B, and is clear of the brass plate. It thus forms a link by which, on turning the handle A, the wheel B is turned through an arc of 60 deg., bringing the next slot in the wheel below the coin slot ready to receive another coin. The sector C does not move, and as it is cut away at the left-hand end it allows the coin to fall into the till at the end of the travel. It will be noticed from the shape of this sector that a smaller coin than that for which the meter is designed would fall right through. The size of the slot prevents larger ones being inserted. The wheel B gearing with a pinion turns the spring barrel D one turn, thus winding the spring a definite amount, and a ratchet (not seen in the figure) engaging with a notch in the periphery of the barrel prevents the spring unwinding by the barrel end. The ratio between wheel and pinion is 6 : 1. The barrel arbor is continued underneath, and the portion E below the barrel is threaded. A flanged nut, F, runs on this threaded portion, carrying a loose collar or strap, to which is attached the crank G and one end of the lever H. By means of two pins fixed to the barrel, which pass through two holes in F, this nut is turned the distance of the pitch of one thread up the barrel arbor. This motion works the bell crank M (pivoted at *m*) thus turning N and the cam O. The latter is not only capable of turning about its axis, but, owing to its support being hinged, it moves to the left, pressing against the bar P, which is constantly held up against O by the tension of the spiral spring R, and thus puts the switch on, as can be seen in the figure. The lever H (pivoted at *h*) has a rack at its other end gearing with a pinion, the spindle of which carries the hand, which indicates the amount in pennyworths unconsumed at any moment. As the action of the clockwork unwinds the spring, the nut H is prevented turning by the pins fixed to the barrel, and consequently travels slowly to its original position owing to the rotation of the threaded spindle which carries it. This motion naturally turns the pointer back and

breaks the circuit. The nut F should run easily on the threaded spindle, but there should be no back-lash, which would cause a slightly variable cut-off.

The insertion of a second and third coin in rotation at the same time simply causes the nut to turn one or two more threads respectively further up the spindle.

The counter S, which indicates the number of coins inserted, has a pinion gearing with the wheel B. The ratio of the wheel and pinion being 6 : 1, the counter increases its reading by one for every coin inserted.

In the older meters of this make the number of double beats per ampere per minute depended on the size of the meter and rate per unit, but this has now been standardised, and one of the wheels in the train is marked and can be seen through a window in the top of the upper cover. Wheels of different ratios are inserted in the clock train which enable the marked wheel to run at a standard speed. In meters for from 100 to 150 volts, this marked wheel should turn one revolution in 100 seconds for every 1·35 amperes flowing, and in those for from 200 to 250 volts one revolution in the same time for every 0·635 ampere flowing.

The meters are made for penny coins and sixpenny pieces, and as the escapement wheel of the former contains only two teeth, whilst that of the latter contains 12, the speed of the marked wheel is unaffected by the coin for which the meter is designed. The remarks made with reference to overloading of the ordinary meter of this make are applicable to the prepayment type, as the current-integrating part of the meter is practically the same.

The prepayment mechanism has been found to work satisfactorily in practice. There is one improvement, however, which might be suggested. The provision of a plain sector, attached to the right-hand side of the arm carrying the handle, would prevent the insertion of a coin unless the slot in the arm was immediately under the slot in the brass plate. At present, if the spring which pulls the arm back against the right-hand stop becomes weak, or if the arm should stick on its backward journey, a coin inserted would fall straight through into the till, or would prevent the arm returning to its normal position, and in either case put the consumer to inconvenience.

The Reason Prepayment Meter.—In the prepayment meter manufactured by the Reason Mfg. Co. the coin actuates the mechanism without the aid of any handle to be operated by the consumer. The external appearance of this meter is seen in Fig. 112. The till is a cast-iron box which is hooked on the

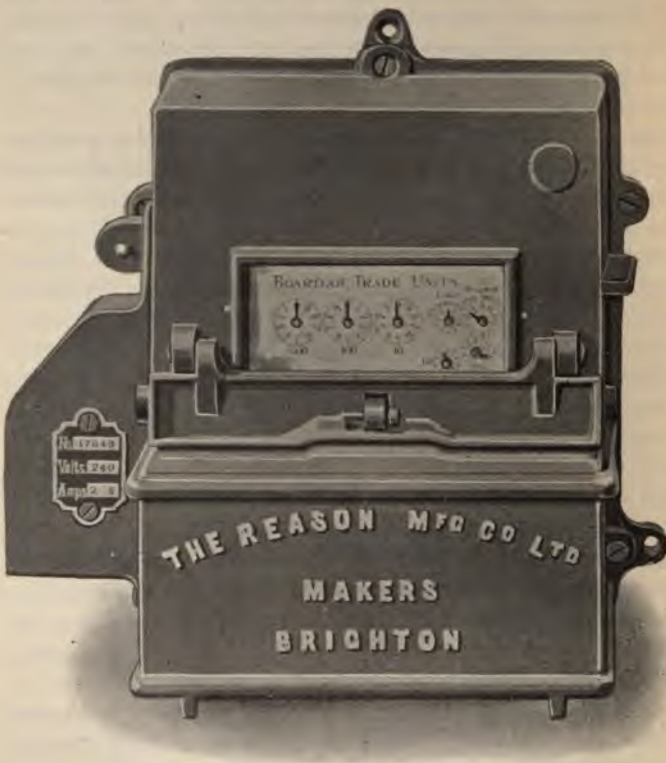


FIG. 112.—REASON PREPAYMENT METER.

left-hand side of the meter, being secured by a hasp and padlock at its upper end. A hinged door just below the dial windows enables the meter terminals to be got at for the purpose of connecting into circuit without breaking the main cover seal. Fig. 113 is a back view of the meter out of its case, and

shows the prepayment mechanism. The meter itself is of the same type as the ordinary mercury motor meter of the same make previously described (Chap. III., p. 82). The prepayment mechanism is shown in detail in elevation in Fig. 114 and in plan (with the coin shoot A and the driving train of the meter removed) in Fig. 115. The upper end of the top portion of the coin shoot A receives the coin when it

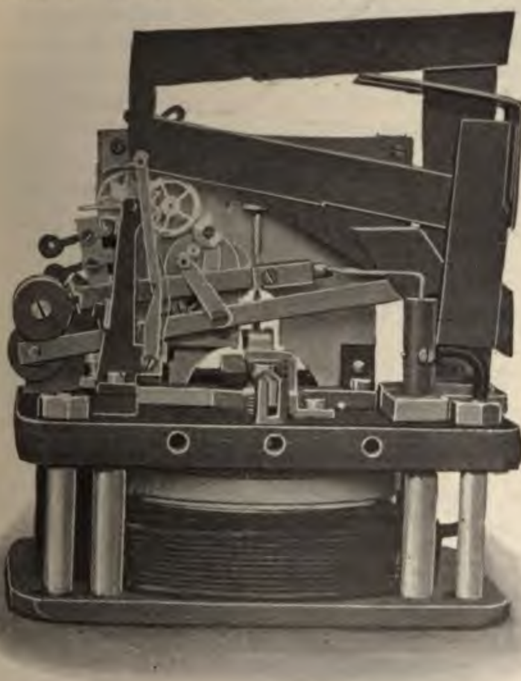


FIG. 113.—REASON PREPAYMENT METER REMOVED FROM CASE.

is put into the slot. In some meters the slot is exactly in front of A, whilst in others a chamber is provided to receive the coin which is pushed sideways by a pusher (which comes out through the front of the case) until it comes opposite the shoot. The object of this device is to prevent all possibility of fraudulently working the mechanism by a wire or otherwise. The coin runs down the upper shoot A, falling

into the lower one at the left-hand end, and on running down this shoot encounters the coin receiver B which is fixed to the lever C. This lever, being pivoted at *c* and slightly overbalanced by a weight at its left-hand end, always remains so that B is in the path of any coin which may be inserted. The coin on passing over the bottom of B deflects the lever C and then runs into the till.

A second lever, E, pivoted at *e*, and balanced similarly to C at its left-hand end, carries a stiff wire, E_1, which forms the arm

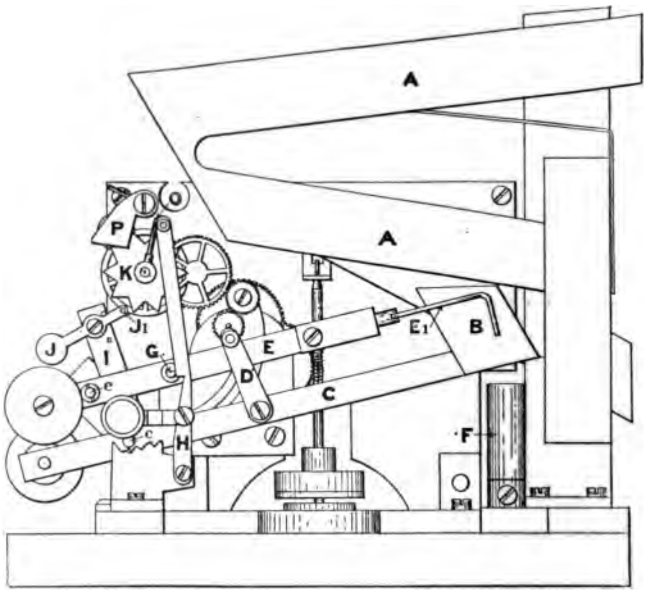


FIG. 114.—ELEVATION OF PREPAYMENT MECHANISM OF REASON METER.

of the mercury switch FF. When the coin deflects the lever C, it also brings the lever E down with it by means of the bar D (rigidly fixed to C), which is fitted with a pin above E, as seen in the plan (Fig. 115). This causes the wire bridge-piece E_1 to dip into the mercury cups and complete the circuit. The notch in the rod H, which is pivoted at the bottom, engaging with a pin, G, on E prevents E rising, and thus breaking the circuit, until G is released, which is effected by the pin O pushing H to the right at the proper time. The normal

position of O is as shown in the elevation. It—together with the arm carrying the planet wheel N of a differential gear—is rigidly fixed to the spindle M_1, which also carries the pointer of the "unconsumed coins" dial. The two crown wheels L and M are fixed to sleeves which are loose on the spindle M_1. A star wheel K, fixed to the same sleeve as L, is turned one tooth for each coin by the pin J_1 on the pawl J, which is carried by the bar I rigidly fixed to the rocking lever C. A pawl, P, locks K, and so prevents it from moving backwards or forwards except when pushed by J_1. The other crown wheel M is geared by a pinion on its sleeve to the wheel-train of the meter. Thus the coin turns O in one direction and the meter-train in the other, and by the insertion of varying

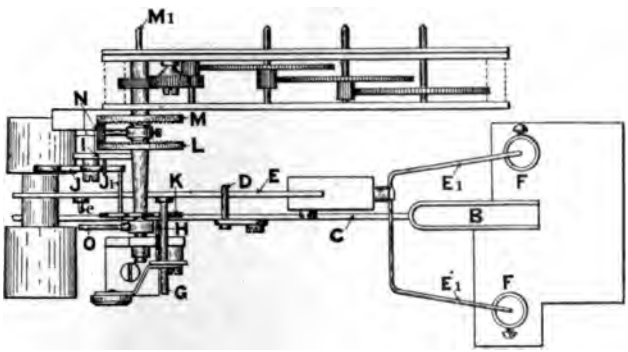


FIG. 115.—PLAN OF PREPAYMENT MECHANISM IN REASON METER.

change wheels in the train which works M, the price per unit can be altered.

Owing to the method by which the coin actuates the mechanism, the working would probably be unreliable with small coins, such as a sixpenny piece. The meter is, therefore, only made for larger coins. In the case of meters to take penny pieces an arrangement is provided which prevents halfpence or small coins working the mechanism, such coins being shot direct into the till.

The mercury switch is probably the meter's greatest drawback, from the supply company's point of view. The mercury cups are certainly easily filled *in situ* through the gap left when the till is removed, but they are less easily emptied. If the

makers were to supply soft rubber caps to fit over the mercury cups during transit, the caps being chained to the meter so that they would be handy when the meter was taken down, this would, in the Author's opinion, be a great though inexpensive improvement.

The Vulcan Prepayment Meter.—This meter consists of an ordinary small pattern Vulcan meter (*see* chap. IV., p. 127), with a prepayment attachment, enclosed under one cover. It probably stands by itself as being the only prepayment meter of the watt-hour type suitable for both alternating and continuous-current circuits. Figs. 116 and 117 illustrate a meter of this make with its cover on and off.

FIG. 116.—VULCAN PREPAYMENT METER.

The dials to the left of the figures are the ordinary meter dials and indicate Board of Trade units. The three upper dials on the right show the number of coins inserted, whilst the lower one on the same plate is the "unconsumed coin" index. The slot to receive the coins is to the left of this dial plate, and the shaft underneath it protrudes through the case and carries a handle (removed in Fig. 117), by which, with the aid of the coin, the mechanism is worked and the switch turned on.

The meter illustrated is fitted with eight small brake magnets (four at the back and four in front), but, as in the case of the ordinary meter, the prepayment type is now made with only four magnets, these being larger and of better design for retaining their strength. Fig. 118 is a view of a meter of this make from above, and shows some of the mechanism. The ordinary dial train A is connected to the prepayment mechanism by means of a crank, B, fitted either on to the worm-wheel spindle (as in Fig. 118, in which case this spindle is made to extend beyond its back bearing to receive it), or on to the spindle of an additional wheel when the speed requires to be slower, as in the case of meters for silver coins.

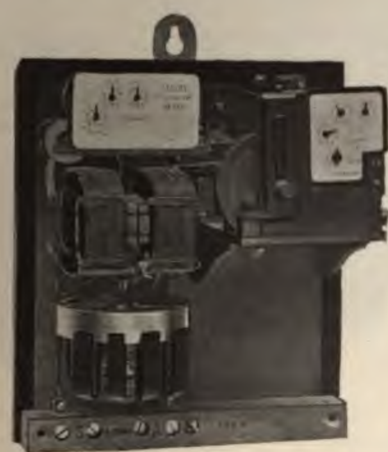


FIG. 117.—VULCAN PREPAYMENT METER. COVER REMOVED.

The crank runs between the two prongs of a forked lever, C, and, by causing the latter to oscillate, operates an escapement which terminates a clock train worked from the opposite end by a strong main spring, D. By this arrangement the main spring is unwound at a speed proportional to the speed of the meter's main moving part, that is, at a speeed proportional to the energy passed through the meter. As the main spring provides the necessary power for working the wheels of the clock train, and as also the forked lever is nicely balanced, there is

practically no extra work thrown upon the meter by the prepayment mechanism. The other mechanism necessary is that for enabling the main spring to be wound a definite amount, at the same time closing a switch which is opened automatically when the meter has unwound the spring by the same amount.

The main spring arbor carries two bevel wheels, E and F, which are on sleeves, and a spindle fixed to it carries the planet wheel G. The wheel E is in gear through the clock train with the escapement, and F gears with the coin-indicating dials and a large toothed wheel immediately underneath the lever H.

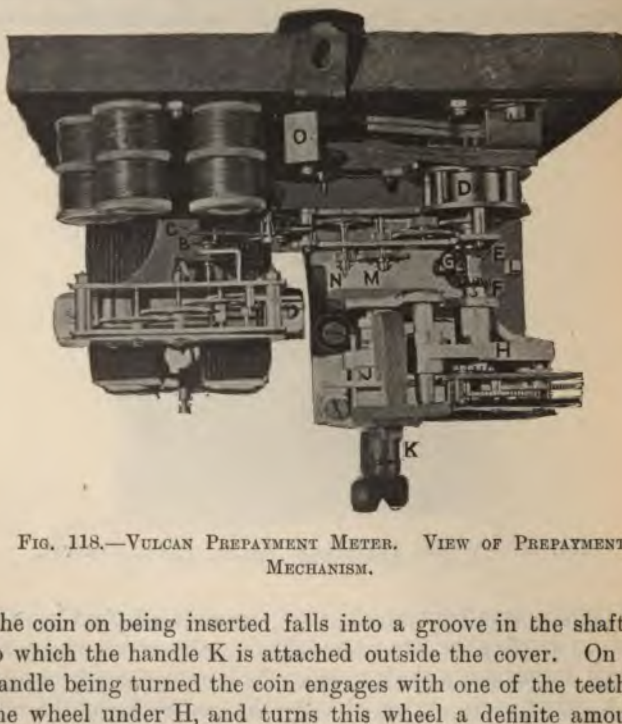


FIG. 118.—VULCAN PREPAYMENT METER. VIEW OF PREPAYMENT MECHANISM.

The coin on being inserted falls into a groove in the shaft J, to which the handle K is attached outside the cover. On the handle being turned the coin engages with one of the teeth in the wheel under H, and turns this wheel a definite amount, controlled by a spring ratchet (not seen in the figure).

As the bevel wheel E is practically stationary (even if the meter is working at the time) the planet wheel G is turned by F, and runs on E, thus turning the arbor and winding the spring. Each additional coin inserted, up to the maximum of

eight, winds the spring an equal amount. By the time the eighth coin has been inserted G will have turned round to the other side of the spring arbor, where it jams up against a lever, L, which locks the shaft and prevents the insertion of further coins until the spring has been unwound to the extent equal to one or more coins by the meter. The power of the main-spring is transmitted to the train through the same planet wheel G, which, as the spring unwinds, runs round in the reverse direction on the bevel wheel F, which is stationary except when the handle is being turned.

To facilitate alteration in the rate of charging, the spindles which carry the change wheels extend beyond the plate and

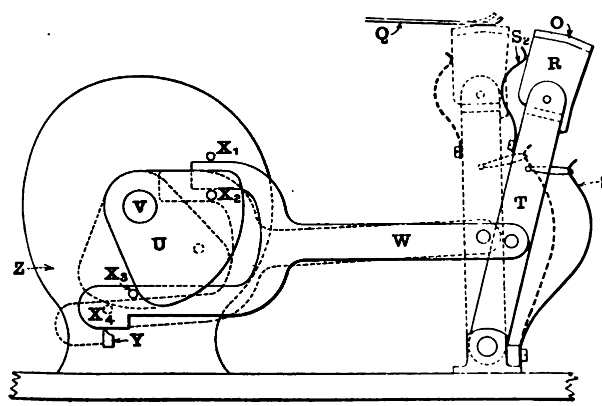


FIG. 119.—SWITCH-GEAR OF VULCAN PREPAYMENT METER.

the wheels are pinned on outside, as at M and N (Fig. 118), thus enabling them to be replaced by others of a different ratio without taking the prepayment train to pieces.

The switch consists of the prongs fixed to the slate back at the top right-hand corner (Fig. 118), which are electrically connected by the plate O, fixed on an ebonite block which is pivoted at the top of an arm, which in turn is pivoted at its lower end. The switch-working mechanism is seen in Fig. 119, which is an elevation of it looking from the back (with the slate back of the meter removed). In this diagram O, R, T are the brass plate, pivoted ebonite block, and arm respectively. The spring S_1 tends to pull the switch off, while a

small spring, S_2, keeps R in the position shown. The pivoting of R allows the upper portion of the switch arm to roll off, and thus prevents rubbing friction between O and the forks of the switch Q when S_1 pulls the switch off; in this way any likelihood of the switch remaining on when it should come off is prevented. The switch is pulled on and released by the sector U (rigidly fixed to the end of the main spring arbor V), which works the fork-shaped connecting rod W by means of the pins X_2, X_3.

The fork of W lies between the sector U and the plate Z (behind which is the main spring D, Fig 118). The pin X_2 is fixed to the sector and stands out behind it so as to catch the upper limb of W; X_3 is fixed to the lower limb of W, which is notched as shown; X_1 is another pin, fixed to the plate Z, and prevents W rising further than necessary. On winding up the spring the sector U is turned into the dotted position, thus pushing X_3 until the notch in the lower limb of W engages with the catch Y, which is fixed to Z. This action puts the switch on, and it will be seen that further winding and consequent turning of U does nothing, but the shape of U prevents all possibility of the switch being released while its periphery is above X_3. When U is in the dotted position, and beyond, X_3 remains at the dotted position X_4, the switch being held on by Y against the tension of the spring S_1. On the main-spring being unwound by the action of the current passing through the meter, the sector U returns, eventually reaching its original position (provided that no further coins are inserted). On its return, X_2 in due course engaging with the upper limb of W, raises the lower one off Y, allowing the spring S_1 to pull the switch off.

The prepayment meter possesses a lower torque than the ordinary meter of this make. A mean of several results on different meters gives a full-load torque of 3·7 gr. cm.; the shunt current is, however, unaltered, it being 0·02 amperes. The meters are made in two sizes—viz., 2 and 3 amperes, for various voltages. They can be obtained for any rate of charge between 3d. and 1s. per unit, to take either pennies, sixpences or shillings. The prepayment mechanism, although appearing somewhat complicated, has been found to give very little trouble in practice.

The Watson Prepayment Meter.—The Watson prepayment meter, or, as it is called, "The Watson Electric Slotter," consists of two independent clocks, each worked by its own mainspring, and a "feeler" ammeter, in addition to which is the mechanism for making the circuit of a main switch when a coin is inserted, and breaking it when the amount of current, or, more correctly, the number of 8-c.p. lamp-hours prepaid, has been taken. Fig. 120 shows a meter of this make with

FIG. 120.—WATSON PREPAYMENT METER. DOOR OPEN.

the hinged front open. The coin is inserted in a slot in a trap in the top left-hand corner. The trap is then turned until the slot is underneath when the coin falls by gravity into a groove, and by bearing against one arm of a bell-crank lever causes the other arm to release the shaft which carries the handle, an adjustable sector, and the eccentrics by which the switch is operated. The objects of the trap are, (1) to prevent all chance of tampering with the meter, either by a wire or by means of

a coin with a thread attached to it, for the purpose of hauling it back; and (2) to prevent bent coins being inserted and jamming. A bent coin will stick in the slot in the trap, and, therefore, has to be turned out again and another one used in its stead. On turning the handle in a clockwise direction the coin falls into the shoot fixed inside the front. The sector fixed on the same shaft as the handle turns a circular disc fixed on the same spindle as the dial hand a definite amount, depending on the price per unit to be charged, or, rather, on the number of 8-c.p. lamp-hours allowed for the penny or shilling, as the case may be; the switch is also closed by the same operation.

The disc and hand are turned back to their original position (zero) by the upper clock, its speed being controlled by an escapement. This escapement is worked at a speed proportional to the number of lamps on and the time for which they are on.

Referring to Fig. 120, the aluminium plate A has a zig-zag slot cut through it, and its lower edge is cut so as to form a series of notches. A pin on the upper escapement passes through the zig-zag slot. The plate A is capable of being turned through a small arc about the axis a, and in turning through the complete arc the pin guided by the zig-zag slot works up and down, thus releasing a tooth of the escapement wheel each time it passes up or down one of the straight slots in the zig-zag. The arc traversed by the plate A is controlled by the arm B, which is pivoted at b and carries on its lower end the core C of the fixed solenoid D, through which the main current passes. The arm B is, therefore, in reality an ammeter needle. There are the same number of notches in the lower edge of A as there are straight slots in the zig-zag, and the notches are cut so that, whichever notch is caught by the arm B, the pin which works the upper escapement is slid along the same number of straight slots of the zig-zag. Thus if one lamp is on, and the plate A allowed to "feel" for the arm B, the latter catches the former in the first notch, causing one tooth of the upper escapement to be released. The plate rests thus on B until a cam wheel in the train of the lower clock comes round and raises the plate A off B, which it does by acting on a pin fixed to an extension of A to the left of its axis a. A second tooth is released by the backward motion of

the upper end of A to its normal or "no current" position. When no current is flowing B should be underneath the zero mark, which is on the plate A to the left of the first notch. In this position the cam wheel only just raises A sufficiently to allow the arm B freedom, but not enough to allow the upper escapement to move. The plate A is raised off B—at regular intervals of about 10 minutes—by the cam, and at these times, should any lamps be on, B being relieved of the plate A, takes up a position according to the value of the current passing. When, therefore, the plate again feels for the arm, after a further interval of 10 minutes, should the current have altered in the meantime, B catches the plate in the second, third or other notch, depending on whether two, three or more lamps are on, and thus four, six, &c., teeth are released in the upper escapement, two for each notch; the hand is, therefore, worked back to zero at a speed proportional to the number of lamps on and the time during which they are on. The scale over which the pointer passes is calibrated in 8-c.p. lamp-hours, and the reading of this scale shows the number of 8-c.p. lamp-hours still standing to the credit of the consumer at any time, and takes the place of the usual "coins prepaid" index. A revolving scale at the back passing a fixed index shows the total number of lamp-hours paid for. This index can be inspected through the hole E in the dial.

The switch and terminals are seen to the left of Fig. 120. The switch is in reality only a single-brake one (although it looks like a double-brake one), as only one of the arms comes out at a time. On the insertion of a second coin the switch is opened at the start of turning the handle, and remains so until the turning is completed, which is rather an objectionable feature, as, apart from putting the lights out—should any be on at the time—bad arcing may take place if the handle is turned at all slowly, and this on a 200-volt supply might damage the switch.

The accuracy depends on many points, such as the proper calibration of the ammeter movement, and the cutting of the notches in A which catch the tip of the arm B; the accurate time-keeping of the lower clock; the amperage of the lamps being uniform and the same as the assumed value for which the meter has been calibrated; and on the fact that it must

not on any account be overloaded. This is an important drawback, as if more than the full load were on, the meter would not cut off the light any quicker than at full-load.

The meter is usually calibrated in 8-c.p. lamps, taking 33 watts per lamp at constant voltage. It could, of course, also be used on circuits installed with 16-c.p. lamps on the assumption that these take twice the power, but it is essentially a lamp-hour meter as distinct from an energy or an ampere-hour meter.

The changing of the rate of charging is very simple in this meter. The sector which turns the metal disc and pointer round—thus crediting the consumer with a certain number of lamp-hours—is made in two portions, one behind the other. The front portion is slotted, and they are both clamped together by a screw which passes through the slot and screws in the back portion. The arc of the sector can thus be increased or diminished within certain limits. As the latter turns the disc by a friction contact of the two peripheries, the longer the arc of the sector the greater is the angle through which the disc and pointer are turned, which means the greater the number of 8-c.p. lamp-hours put to the credit of the consumer for the coin.

This meter is made in two sizes—viz., 3 and 10 lamps. The two clocks require winding by hand once a month.

CHAPTER VI.

DOUBLE-TARIFF METERS AND MAXIMUM DEMAND INDICATORS.

The fact that the cost of production of electric energy depends to a much greater extent on the rate at which it is supplied than on the quantity supplied during a given period, and that a flat rate of charging takes no account of the rate at which the energy is taken by the consumer, or the time of day at which he takes it, has led to the introduction of other methods of charging. These may be divided into two classes, viz.: (1) those which require no special measuring apparatus other than the ordinary integrating meter, and (2) those which require either specially designed meters or additional apparatus. The first class consists of systems in which discounts are given in proportion to the quantity of energy consumed, or those in which the discount is varied according to the probable duration of the demand of the consumer. The second class practically consists of two: the differential tariff and the maximum demand systems. With the differential tariff system a high rate is charged during the evening when the station is very fully loaded—or during the peak of the load—and a low rate during the rest of the 24 hours. This method of charging therefore tends to encourage the use of electricity during the period of light load, and to discourage its extravagant use at the time of maximum load on the station, thus tending to reduce the peak and increase the load-factor. It necessitates the use of two-rate meters, or of time switches in conjunction with ordinary meters. This system is extremely simple, and is therefore easily comprehensible to the consumer. The B.T. units consumed are recorded on two sets of dials in the meter (or by two meters), according as to whether they have been

M 2

consumed during the high or the low-rate period into which the 24 hours are split up. These periods may be altered according to the time of year, in order that the high-rate period may be during the peak, which generally takes place at different times in summer and winter. With the maximum demand system the consumer is charged at a high rate for the equivalent of one or two hours' (as the case may be) daily use of his maximum demand, and a low rate for all units consumed above this quantity. This system gives enormous advantages to the long-hour consumer who does not exceed his usual load at any time during the quarter, or half-year, and under it the short-hour consumer has to pay a high price, owing to his consumption never reaching the quantity necessary to be consumed before the rebate comes into force. The long-hour consumer who exceeds his usual maximum only once or twice during the period has to pay very heavily for doing so.

The adoption of this system introduces an additional instrument, called a maximum demand indicator, which is fixed on the consumer's premises in addition to the ordinary meter. The demand indicator is really a sluggish non-return ammeter. It requires to be made sluggish in order not to take account of any momentary increase of load, such as the switching on of lamps in one room just before the switching off of those in another, or, in the case of motors, its reading should not be affected by the starting current, for such temporary loads have no effect on the capital costs of the undertaking, and the system of charging would become rather a system of fining the consumer for carelessness. The amount of sluggishness required depends to some extent on the kind of load on which the instrument is to work: for example, a very sluggish instrument on a lift motor circuit would give no indication of the maximum demand, for the load would be too intermittent. The consumption being ascertained from the meter, and the highest steady load in amperes from the demand indicator, the amount of the bill is ascertained from these quantities as follows:— Assuming that the rate is 6d. for the first two hours' consumption per day of the maximum demand during the quarter of 91 days, and 2d. for all units consumed after this amount, and that the meter showed a consumption of 50 units, the pressure of supply being 100 volts, then, if the maximum demand, as

shown by the reading of the demand indicator, be greater than or equal to

$$\frac{50 \text{ units} \times 1{,}000}{100 \text{ volts} \times 91 \text{ days} \times 2 \text{ hours}} = 2\cdot74 \text{ amperes,}$$

the 50 units would all be charged for at the 6d. rate, and the quarter's bill would amount to 25s. If, however, the maximum demand had not exceeded 2 amperes, and the same number of units had been consumed, then

$$\frac{100 \text{ volts} \times 2 \text{ amperes} \times 2 \text{ hours} \times 91 \text{ days}}{1{,}000} = 36\cdot4 \text{ units}$$

would be charged for at the 6d. rate, and the balance, $50 - 36\cdot4 = 13\cdot6$, at the 2d. rate:

36·4 @ 6d. =	18s. 3d.
13·6 @ 2d. =	2s. 3d.
	£1. 0s. 6d.

The above examples show how the charge for a given consumption is modified by the maximum demand.

The question of charging by this system, as also the method by which the theoretically correct prices to be charged are arrived at, is entered into very fully in a Paper read before the Institution of Electrical Engineers,* entitled "Some Principles underlying the Profitable Sale of Electricity," by Mr. Arthur Wright.

In order to facilitate the making out of accounts, maximum demand indicators, which indicate the maximum amperes, are usually provided with a scale in addition to the one indicating amperes. This second scale is often calibrated to indicate the number of units to be consumed per quarter (or half-year or year, as the case may be) before the reduced price is charged. If there is any likelihood of the rate being altered, it is not advisable to have the second scale calibrated in this manner. It can then be made to indicate the maximum kilowatts used, or the number of 8 c.p. lamps used simultaneously on incandescent lighting circuits. By altering the rate for winter and summer, for example, allowing the reduced rate to come into force after the consumption equivalent to the use of the

* *Journal* I.E.E., Vol. XXXI., No. 155, pp. 441 to 530. Also *The Electrician*, Dec. 12, 1901.

maximum demand for, say, 1½ hours per day in summer, and for 3 hours in winter, a more proportionate rebate is obtained, and in such cases it may be convenient to have two scales—one for summer and one for winter—calibrated in units to be consumed before the reduced price comes into force. In this case the winter scale would show double the number of units to the summer one for the same number of amperes.

DOUBLE-TARIFF METERS.

The Aron Two-rate Meter.—This instrument consists of an ordinary meter of this make (*see* Chap. IV., p. 95) coupled

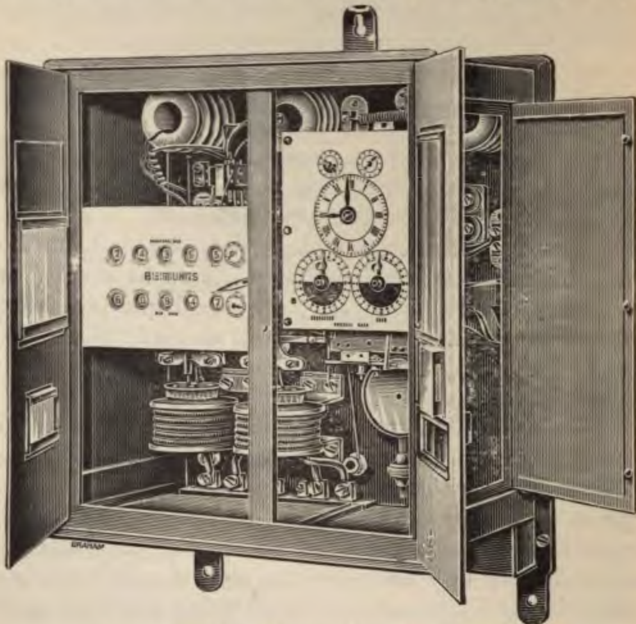


FIG. 121.—ARON DOUBLE-TARIFF METER. OPEN.

with a clock having slight additional mechanism, the whole being contained in one case. The meter portion of the combination is provided with two distinct sets of dials, one for indicating the number of units consumed at one rate of charge and the other for indicating those consumed at the second rate. Each set of dials is thrown into, and out of, gear with

the meter by means of a simple change-over mechanism, to which is attached a pointer, which indicates at any time the set of dials on which the consumption is being recorded. Fig. 121 illustrates a meter of this make with the three doors open. The clock is seen in the right-hand compartment of the case and the meter in the left-hand one. The meter illustrated is fitted with the springing figure dials (*see* Chap. II., p. 17), but the instrument is also made with pointer dials. The clock face, as will be seen from Fig. 122, contains, in addition to the ordinary time dial, four others. The upper one on the right is simply a seconds dial and is used in regulating the clock, it

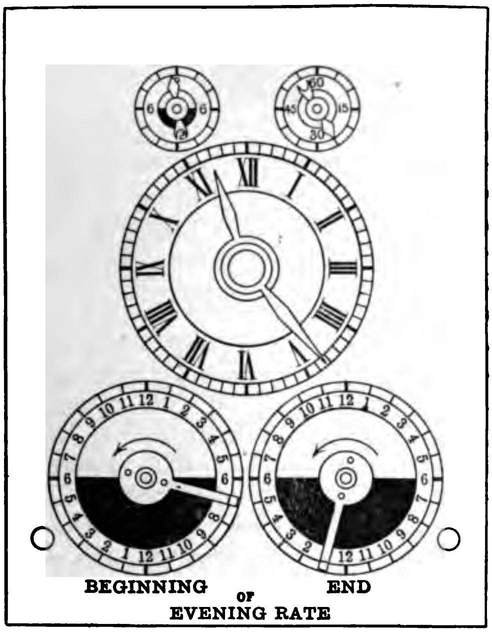


FIG. 122.—CLOCK FACE OF ARON DOUBLE-TARIFF METER.

being very essential that the clock keeps time accurately. The upper left-hand dial is divided into 12 spaces, each representing two hours. The lower half of this dial is blackened and represents night, the upper half representing day. In setting the clock hands to the correct time this dial has to be consulted in order to ascertain that the clock is set correctly

to time, having regard to day or night. For instance, in Fig. 122 the clock is indicating 11:23 a.m., the a.m. being ascertained by inspection of the upper left-hand pointer. Should the clock be set 12 hours late, the evening-rate dials would record the day-rate units.

The periods of the 24 hours during which the high and low rates are in operation is easily altered to suit varying requirements by means of the hands on the two lower dials. These hands are turned in a counter-clockwise direction, as shown by the arrows, until they point to the beginning and end of the evening rate These two dials are also divided into the 24 hours, and those parts of each between 6 p.m. and 6 a.m. are blackened so as to represent night. In the dial illustrated the meter is set so that the evening rate commences at 7 p.m. and ends at 11 p.m.

Very often the period during which the high rate is charged is altered for different periods of the year, depending on the time at which the station-load curve peak takes place. The alteration in this meter is extremely simple, all that is required being the resetting of the pointers on these lower dials to the altered times.

A separate electric winding gear is provided for the ordinary clock. The meter pendulums are self-starting when the shunt-circuit is made, but the clock pendulum requires to be started by hand. The clock is provided with an auxiliary spring, wound by the same winding gear, which keeps the clock working 40 hours after the stoppage of the supply, or other cause preventing the excitation of the shunt-circuit. It is, therefore, essential either to connect the meter on the station side of any main switch liable to be broken or to run a pair of shunt leads from the meter to that side of the switch should the meter be connected on the house side of it.

Should the current be off for a longer period than that stated above, it becomes necessary to reset the clock to the correct time and restart the clock pendulum of every meter on the particular circuit. These meters require to be fixed absolutely plumb, as indicated by the point of the clock pendulum being exactly over the fixed point just below it.

To regulate the clock it is necessary to turn a nut below the pendulum bob up or down the screw according as to whether

the clock is required to go faster or slower. About a quarter of a turn of this nut will make a difference of one minute per week or 13 minutes per quarter. The nut being purposely made to fit tightly on the screw, the pendulum should be held firmly with one hand before attempting to turn the nut with the other.

The Electrical Co's Double-tariff Apparatus.—The Electrical Co. have introduced a tariff clock which is capable of being

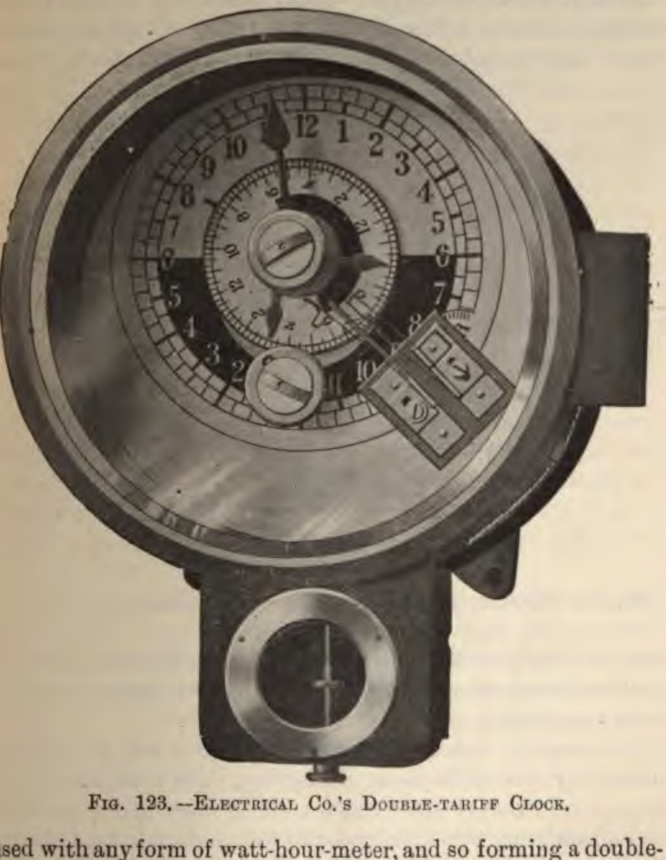


FIG. 123.—ELECTRICAL CO.'S DOUBLE-TARIFF CLOCK.

used with any form of watt-hour-meter, and so forming a double-tariff set. This clock is illustrated in Fig. 123, and shown diagrammatically in Fig. 124. It consists of a pendulum clock having its dial divided into 24 hours, the part from

6 p.m. to 6 a.m. being blackened (Fig. 123). On the hour-hand barrel of the clock a smaller disc, similarly divided into the 24 hours, is fixed, and two sectors, A, B (Fig. 124), are also carried by the hour-hand barrel by which they are turned by friction, being loose enough to allow of setting. These sectors are provided with a red and a green pointer respectively, which indicate the times of switching on and switching off of the shunt current of a watt-hour meter. The consumption shown by this meter, therefore, indicates the number of units taken at the high rate. A second meter, whose shunt is not interfered with by the tariff clock, is also

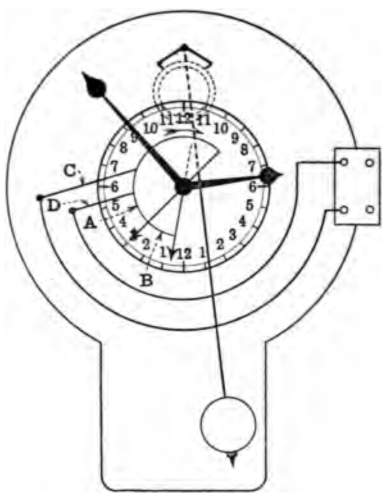


FIG. 124.—CONNECTIONS OF ELECTRICAL CO.'S DOUBLE-TARIFF CLOCK.

used and registers the total consumption, so that the difference between the consumption shown by the two meters gives the units consumed at the low rate.

The sectors, which are one behind the other, as they are turned by the clock come up against light springs. These springs are fixed at their other ends to brass plates mounted on an insulating block. In order to reduce the friction between the sectors and the springs, which, if great, might interfere with the rate of the clock, the tops of the springs are fitted with very small glass tubes, which act as wheels rolling round when

they are in contact with the peripheries of the sectors. They also insulate the springs from the clock.

The time during which the shunt-circuit of the high-rate meter is made is altered by setting the red and green pointers to the hours on the small dial at which it is desired that the high rate should start and finish, the red one being set to the starting and the green one to the finishing time. It is important first to set the tariff pointers and *then* set the clock hands to the correct time, otherwise it is possible to damage the spring contacts. For continuous-current circuits, the Electrical Co. mount one of their oscillating type meters (*see* Chap. III., p. 62), an additional relay and dials and a tariff clock on one board, the set being very neatly connected up, leaving only the insertion of the mains into the meter terminals when erected. In this case it is only necessary to have the one meter with two counting mechanisms. The additional counting mechanism is in circuit with the tariff clock contacts, and duplicates the reading during the time when the high tariff is in force.

Hookham Double-tariff Meter.—This instrument is essentially a meter of the 1897 type (which has been previously described, Chap. III., p. 72), fitted with two sets of dials and pointers on the same dial plate, the upper set showing the units consumed during the low-rate period and the lower set those consumed during the high-rate period. The meter is intended to be used in conjunction with a time switch of any suitable make which is capable of making and breaking the circuit of a shunt solenoid contained in the meter.

The last wheel of the meter train is mounted on a rocking arm, and until the circuit of the solenoid is made by the time switch, this wheel is held in gear with the first wheel of the upper (or low-rate) train by gravity. During the period when the solenoid is energised the wheel on the rocking arm is pulled out of gear with the upper dial train and into gear with the lower one, the rocking arm being worked by the core of the solenoid.

As the high-rate period is invariably the shorter of the two, the solenoid is actuated during this period in preference to the other, in order to keep the watt loss in the introduced shunt circuit as low as possible. If any break should occur in this

circuit, therefore, the whole of the units would be recorded on the low-rate dials until the defect were found and remedied. Should the time-switch clock stop from any cause, the consumption might be recorded on either set of dials depending on the time at which the clock stopped.

MAXIMUM DEMAND INDICATORS.

The Atkinson-Schattner Demand Indicator.—This instrument works on the electromagnetic principle. It consists of a

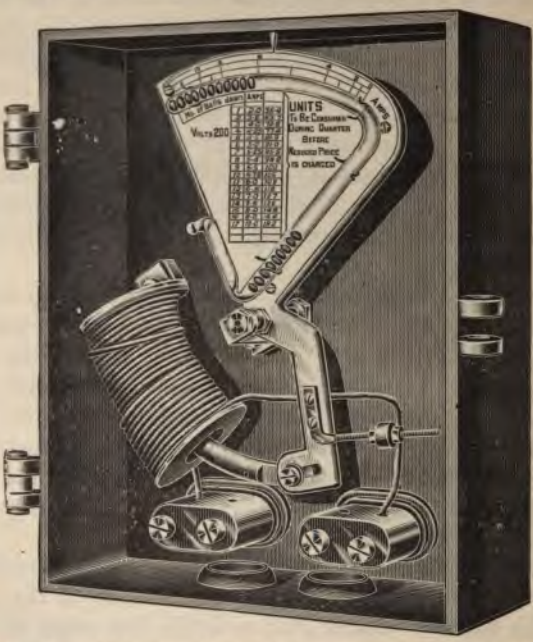


FIG. 125.—10-AMPERE ATKINSON-SCHATTNER DEMAND INDICATOR.

solenoid (through which the main current is passed) into which a core attached to a pivoted frame is sucked against the force of gravity. The upper portion of the frame, which is in the form of a sector, carries a sealed glass tube, which contains a number of balls in a viscous liquid such as oil or glycerine. The tube is mounted on an aluminium scale, as seen in Fig. 125. The upper part of the glass tube is curved to form an arc, the

centre of which is the axis of pivoting. The balance of the moving part is adjusted by a balance-weight screwed and locked to a spindle attached to the lower part of the moving frame which carries the core. A pin, forming the index for reading, is fixed to the top of the case and stands in front of the scale of amperes marked near the rim of the aluminium sector above the curved portion of the tube. Before current passes the instrument is set so that the pointer is at the zero of the scale, and all the balls are in the curved part of the tube. As the highest point of the tube is to the right of the first ball none fall over into the straight portion. On the passing of a current the scale and tube are deflected to the right by the core being sucked into the solenoid; thus, according to the strength of the current, a certain number of balls are carried over the highest point, *i.e.*, the vertical through the centre of pivoting; these balls, therefore, start moving, and slowly fall by gravity into the straight radial part of the tube. The damping depends on the viscosity of the liquid in the tube.

The instrument is calibrated in amperes, and a table is usually placed on the scale giving the amperes and units to be consumed before the reduced rate comes into force per ball found in the radial limb. Each tube contains about 20 balls, so that the range of the instrument is split up into the same number of steps. As the instrument has, therefore, a broken scale, the percentage accuracy depends on the number of steps as well as on the calibration. The percentage inaccuracy at the low readings may be fairly large; for example, on a 30-ampere indicator the following may be the first jumps :—

1 ball down ....3 amperes.
2 balls ,, ...6 ,,
3 ,, ,, ...8 ,,

the middle of the scale becoming more open giving a difference of 0·5 ampere per ball, or about 3·2 per cent., and at the end of the scale about 2 amperes per ball down, or 6·6 per cent.

Fig. 126 shows the curve connecting amperes with the number of balls down in a 30-ampere instrument. Each instrument is usually provided with two scales with tubes attached in order that the indicator may be reset without delay. The resetting

consists in taking the scale (to which the tube is fixed) off the frame and inverting it. The balls then slowly return from the radial leg to the curved portion, but, owing to the sluggishness, this would take some little time. Supports are, therefore, provided inside the door which hold the scale inverted. Placed on these supports it resets itself and is found ready at the time of the next reading, a second scale and tube being attached to the frame instead of the one just removed. A very neat arrangement is provided for fixing the scales to the frame which prevents any chance of their not being placed in the exact position. This demand indicator is suitable for alternating and continuous-current circuits, but requires to be calibrated for the circuit on which it is to work. The cores must be laminated and the bobbins slotted in the case of the alternating instruments, to avoid the generation of eddy currents.

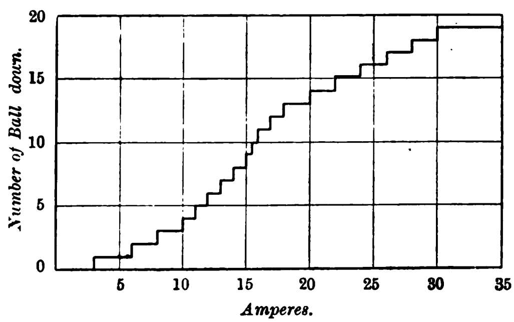


FIG. 126.—CALIBRATION CURVE OF 30-AMPERE ATKINSON-SCHATTNER DEMAND INDICATOR.

The instrument is made in various capacities, from 2·5 to 1,000 amperes, the dimensions up to 50 amperes being $7\frac{3}{4}$ in. × 8 in. × $2\frac{1}{2}$ in., and in the larger sizes $9\frac{1}{4}$ in. × $9\frac{5}{8}$ in. × $3\frac{5}{8}$ in.

The Fricker Demand Indicator.—Mr. G. C. Fricker has recently brought out a new demand indicator which works on the differential thermometer principle, and is remarkable for its extreme simplicity. It consists of a glass tube of uniform bore having two bulbs A, B (Fig. 127), one at each end. In order to make this illustration clearer, it is diagrammatic and not to

scale. This tube contains hydrogen, and is hermetically sealed. Before sealing, a small drop of mercury, C, is put into the tube. The bulb A is placed in a short spiral of bare wire through which the main current is passed. In the larger sizes this spiral is replaced by a strip of metal almost encircling the bulb. The normal position of the bead of mercury is over the entrance of the tube in the bulb B. It will be seen that when a current is passed through the spiral, the temperature of the gas in the bulb A will be raised above that of the gas in B, which is at the temperature of the surrounding air, and owing to the consequent increase of pressure in A some of the gas will be transferred from A to B through the globule of mercury C, which acts as a valve. On the cessation of the current, the two bulbs will gradually attain the same temperature again, when the pressure of the gas in B will cause the globule to pass along the tube to a position, C′, at which the pressure on either side

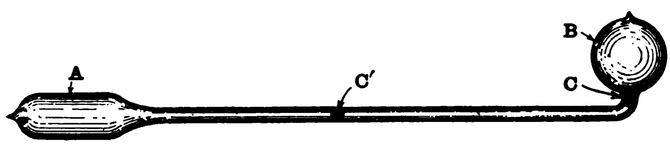


FIG. 127.—DIAGRAM OF TUBE IN FRICKER DEMAND INDICATOR.

of the mercury will be approximately the same. As the amount of gas transferred from A to B during the heating will depend on the current, the position C, which the mercury takes up when the temperatures of A and B again become equal, may be used as an indication of the current which had passed through the spiral; that is to say, a scale indicating maximum amperes can be made having its zero near B and its highest point near A. (The left-hand end of C′ is usually taken as the indicating end.) To obtain the correct reading indicating the maximum amperes passed during any period (such as a quarter), it will be evident that the temperatures of A and B must be the same, thus it would be quite impossible to ascertain this maximum reading if any current were passing at the time, for the position taken up by the mercury will depend on the difference of the temperature of A and B. In practice, therefore, the following

procedure is necessary before taking a reading: The tube is removed from its supports and the bulb A is placed in a hole in a sealed-up vessel containing water. This water jacket is fixed to the end of the case near B, and will therefore be at the same temperature as this bulb—*i.e.*, the temperature of the air. The bulb A is left in this water jacket for *one minute* which is stated to be ample time for the gas in it to attain practically the same temperature. The position of the mercury is then read, and the instrument is then reset to zero by holding the tube by the end A and giving it a sharp turn in such a manner that B passes along an arc of a circle of which A is the centre. The tube then being replaced, with A in the spiral, the instrument is again ready for working. The case which encloses the instrument is fitted with a device which automatically allows the spiral to grip the bulb when the door is shut, and releases this grip on the door being opened, thus facilitating the removal of the tube without fear of breakage. In Fig. 128, which illustrates an instrument of this make, this device is seen. It consists of a wedge which presses between two brass springs to which the ends of the heating spiral are attached. The scale of the instrument is firmly fixed to the tube. The water jacket is attached to the inside of the right-hand end of the case, which is hinged to allow of the removal of the tube

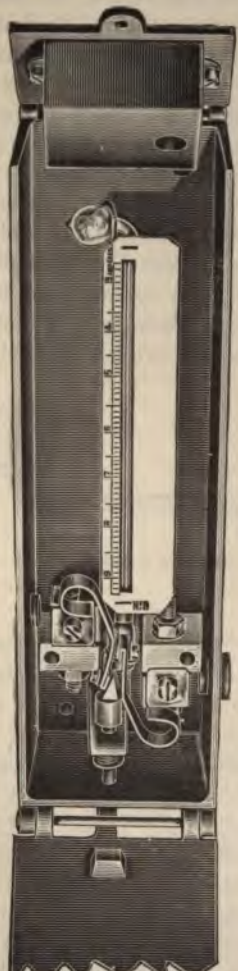


Fig. 128.—Fricker Demand Indicator with Cover and End Open.

and the insertion of the heated bulb into the hole provided for it in the water jacket.

The calibration curve of a demand indicator of this make is seen in Fig. 129.

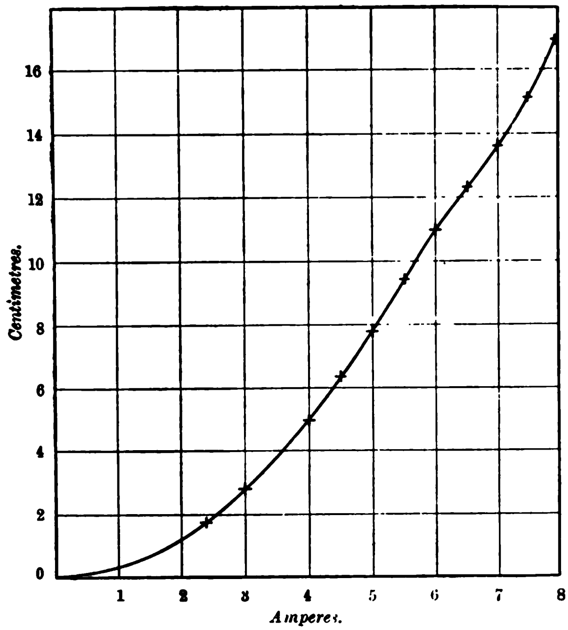


FIG. 129.—CALIBRATION CURVE OF FRICKER DEMAND INDICATOR.

The Reason Mfg. Co.'s Demand Indicator.—This company manufacture three types of demand indicators—viz., the electro-magnetic type, the Wright demand indicator, and an instrument devised by Mr. C. H. Merz, which is chiefly intended for use in connection with supply-in-bulk schemes.

The electro-magnetic type of instrument consists of a sealed glass vessel of the peculiar shape seen in Fig. 130, mounted on a zinc plate suitably pivoted and to which is attached a core. The main current is passed through a fixed solenoid into which the core is attracted, so tilting the glass vessel and allowing a certain amount of the liquid to pass through the narrow-bore tube A into the long tube. The greater the angle through which the tube is turned by the action of the current on the

core, the higher will the level of the liquid be in the long tube. The height of the liquid in this tube, therefore, is a measure of the maximum current. A scale is fixed to the plate as seen in Fig. 131, which is a view of a 200-volt 5-amp. instrument with its cover removed. The right-hand scale indicates the maximum current in amperes used, and on the left of the tube is a scale indicating the number of units to be consumed during the quarter before the reduced price is charged, *i.e.*, the number

FIG. 131.—REASON ELECTROMAGNETIC DEMAND INDICATOR. OPEN.

of units which will be charged for at the high rate. In the instrument illustrated this scale is plotted for 1 hour's use per day of the maximum demand.

A counterweight fixed on an arm attached to the moving system enables the reading tube to remain vertical when no current is passing, and sufficient liquid is put into the glass vessel to allow a little to overflow when in this position, giving

a zero mark. In erecting the instrument, the proper level is ascertained by the arrow on the bottom of the reading tube and the index fixed to the case. During transport the moving system is clamped by the screw and washers, A (Fig. 132) which are removed and screwed into a tapped hole, B, in the case to prevent their being lost. The plate holding the glass vessel is supported on a brass bracket (seen in Fig. 133) by a spindle D

Fig. 130.
Tube of Reason Electro-magnetic Demand Indicator.

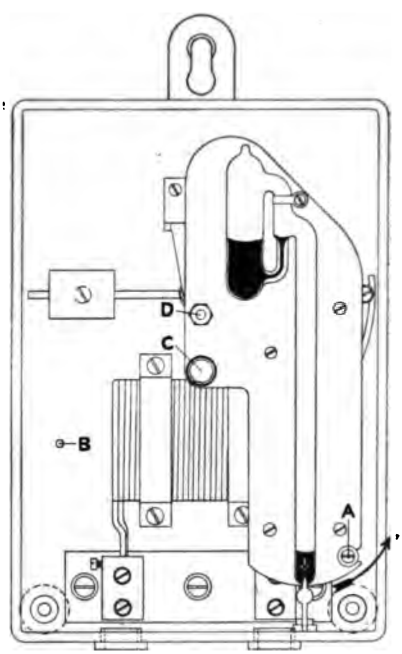


Fig. 132.
Reason Electromagnetic Demand Indicator.

(see also Fig. 132), about which it is capable of being turned in the direction of the arrow, when a thumb screw, C, is removed for the purpose of resetting to zero. When the reading tube has been emptied, C is replaced and holds the plate rigidly fixed to the supporting bracket. The whole moving portion is

supported by the steel spindle, the ends of which are turned to a small diameter and rest in bearing holes.

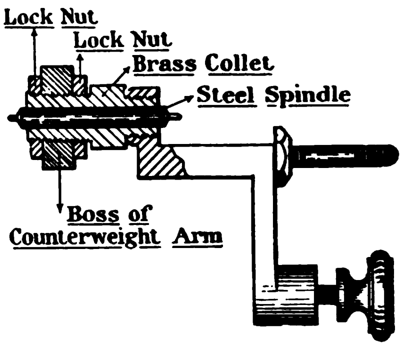


FIG. 133.—SUPPORTING BRACKET OF REASON ELECTROMAGNETIC DEMAND INDICATOR.

A typical calibration curve of this instrument is seen in Fig. 134, which shows that the instrument may be made to have

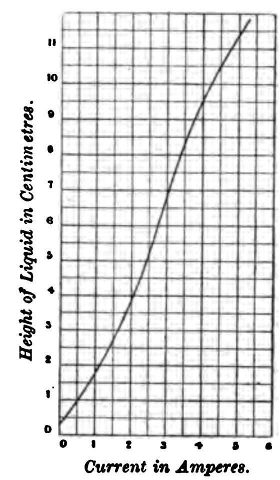


FIG. 134.—TYPICAL CALIBRATION CURVE OF REASON ELECTROMAGNETIC DEMAND INDICATOR.

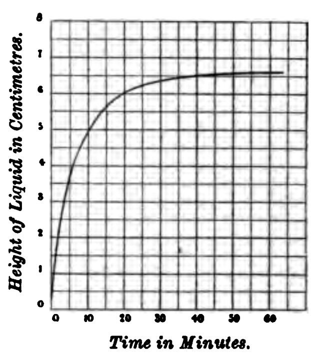


FIG. 135.—TYPICAL TIME CURVE OF REASON ELECTROMAGNETIC DEMAND INDICATOR.

a fairly proportional scale, but, by suitable adjustment of the counterweight arm and core, a scale more open at one part can

be obtained. The sluggishness is increased or diminished by reducing or increasing the diameter of the tube, A (Fig. 130). A typical time curve is shown in Fig. 135. It is stated that the instrument can be made to reach its steady reading in any time between five minutes and three hours.

A short-circuit has no ill effect on the instrument, as springs are provided to take the shock of the moving system which might otherwise damage it. These demand indicators are made in sizes from 5 to 100 amperes with drops varying from 0·43 to 0·03 volts.

The Wright maximum-demand indicator works on the principle of the differential thermometer, and consists of a glass tube, LL, Fig. 136, which is provided with a series of traps in each leg

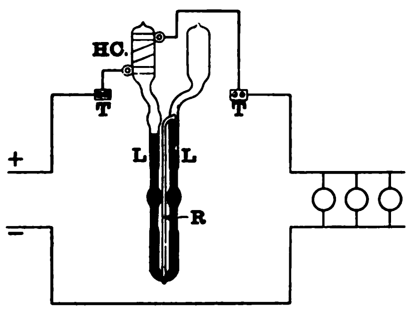


FIG. 136.—DIAGRAM SHOWING CONNECTIONS AND TUBES OF WRIGHT DEMAND INDICATOR.

and terminates at each end in a bulb. These bulbs have, approximately, the same capacity, and one, HC, has wound round it a spiral or strip, through which the main current is passed; the U tube contains a moderately viscous and very hygroscopic liquid, which keeps the air dry in the two bulbs. A tube, R, called the reading tube, is branched off from the right-hand limb of the U tube, and as the air in the bulb around which the heating coil HC is placed expands the level of the liquid is raised in the right-hand tube and some overflows into the tube R. The height of the column in R is a measure of the current passed through the coil, a scale being placed behind R, as seen in Fig. 137, which illustrates the latest pattern of this instrument with its hinged cover open. The glass-tube system

is clamped to a board, the latter being hinged at the upper end. Flexible leads carry the current from the fixed terminals (seen at the top of Fig. 137) to the ends of the heating strip. The instrument is reset to zero by raising the bottom end of the board, carrying the tubes, about the hinges, so that the lower end is above the upper. The liquid then runs out of the reading tube into the right-hand bulb.

Fig. 137.—Wright Maximum Demand Indicator. Open.

After the reading tube has been emptied in this manner, the board is brought down to its normal position, the liquid in the right-hand bulb at once falls into the right-hand tube, and that above the junction of the reading tube falls into it, filling it up to the zero mark, usually denoted by a red line on the scale. The traps, which consist of long glass cones, each having a hole in its apex, prevent the bulk of the liquid from shifting during resetting, and the passage of air from one bulb to the other when travelling or while being reset when hot.

The instrument, working as it does on the thermal principle, is independent of polarity and is suitable for both alternating and continuous-current circuits without recalibration. It is practically unaffected by differences of external temperature, since its action depends on the difference of the temperature of the two bulbs, which contain about the same volume of air and are at the same temperature when no current is passing.

A typical calibration curve is seen in Fig. 138, which shows that a fairly open and proportional scale is obtained between one-fifth and full load.

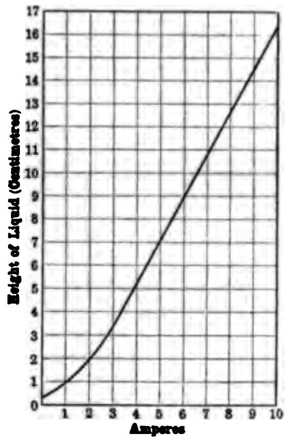


FIG. 138.—CALIBRATION CURVE OF 10-AMPERE WRIGHT DEMAND INDICATOR.

The sluggishness of the instrument is seen in Fig. 139, from which it will be noticed that it is very much the same for all

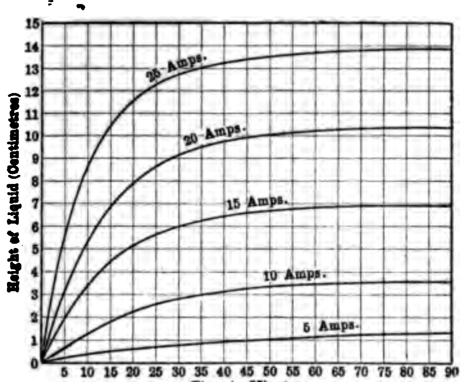


FIG. 139.—TIME CURVES OF WRIGHT DEMAND INDICATOR.

loads. On the instrument becoming cold after the cessation of the current, the level of the liquid in the right-hand tube

falls below the junction of the reading tube, and therefore when a stronger current is subsequently passed it takes a certain time to rise to this point, until when the reading is naturally not affected.

Above 100 amperes capacity the demand indicator is used with a shunt, as illustrated in Fig. 140, but for alternating-current circuits the transformer type (Fig. 141) is to be preferred, especially on high-pressure circuits, as the instrument

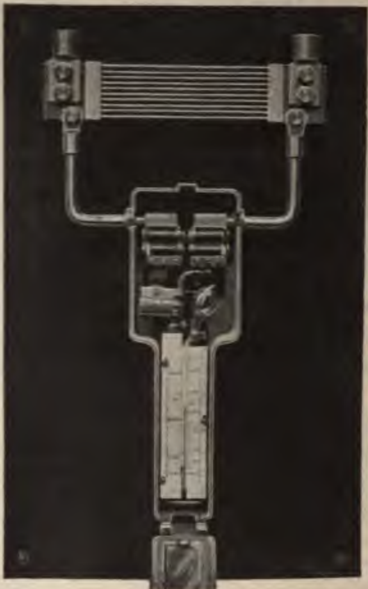


FIG. 140.—WRIGHT DEMAND INDICATOR. SHUNTED TYPE. CAPACITY, 300–1,000 AMPERES.

is insulated from the circuit, an important feature, owing to it having to be handled for resetting to zero.

The indicator, being a current-measuring instrument, takes no account of the power-factor of the circuit, so that on inductive circuits the lower the power-factor of a given *true* kilowatt demand, the greater will be the number of units to be consumed before the rebate is given.

For three-wire circuits a shunted instrument is used in the same manner as the Wright electrolytic meter, which is

described in Chap. III., p. 88, the heating coil of the demand indicator being connected to the two ends of the divided shunt. Here, as in the case of the meter, it is necessary that the cir-

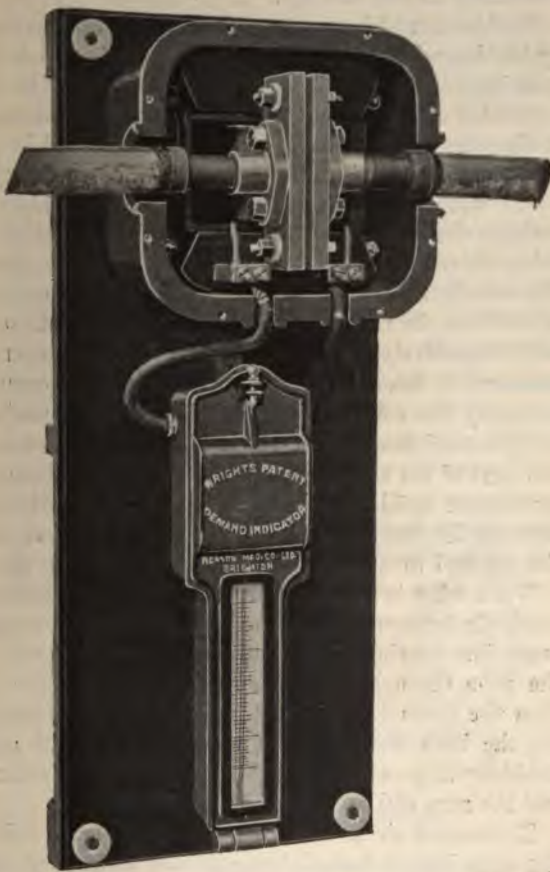


FIG. 141.—WRIGHT DEMAND INDICATOR. TRANSFORMER TYPE.

cuits are split up into two 2-wire circuits on the house side of the instrument (see Fig. 69, p. 89).

Notwithstanding the introduction of the traps previously referred to, air bubbles may get lodged underneath the liquid,

and under the severe jolting which may be encountered on a railway journey in some cases air may be transferred from the one bulb to the other, which alters the zero and causes inaccuracy in the readings.

Bubbles can be brought out from the liquid into the air bulbs by heating with a spirit lamp that bulb to which the bubble is to be returned, until the level of the liquid in the tube is lowered a certain amount, care being taken to heat gradually or the glass will be cracked. The scale should be previously removed. On cooling, the bubble will be drawn up with the liquid and will return to the bulb. If a first attempt proves fruitless the bulb should be re-heated, the level of the liquid being driven down slightly lower than at the first attempt. The zero is raised or lowered by transferring a certain amount of air from the right to the left, or from the left to the right, bulb respectively. To perform either of these operations it is necessary to heat the right-hand bulb—*i.e.*, the one which does not carry the coil—by heating this bulb with the instrument upright until the level of the liquid is driven down to the narrow part of the tube just above the trap, and then turning the instrument upside down; as the bulb cools bubbles of air pass through the first and then through the second trap in the opposite leg, and thus rise to the bend, which is now on top.

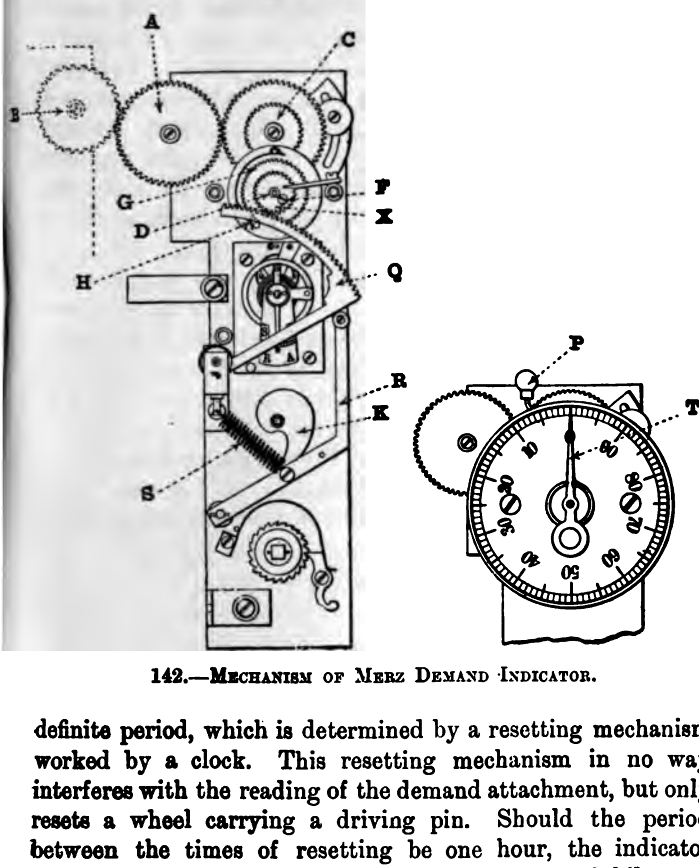
When what is estimated as sufficient air has collected in the bend, the instrument is turned the right way up again, at the same time coaxing the air bubbles round the bend—*i.e.*, under the tube through which they are required to rise—they will then rise through the lowest trap on that leg. On again heating the bulb and letting it cool in an upright position, the bubbles will pass up through the second trap, enter the bulb, and the zero will have been lowered.

To transfer air in the other direction and so raise the zero, the same bulb is heated, but with the instrument *upside down*, until the required amount of air has been driven up into the bend. By turning the instrument the right way up again, and by rocking, the air can be brought under the trap in the left-hand limb. Further heating will then cause the bubble to pass through the traps and enter the left-hand bulb.

When the instrument is again cold, if the right amount of air has been transferred, the zero will be about right. It is,

of course, necessary to test after these operations, and should the instrument not be within the limits of accuracy, the scale can very often be raised or lowered a sufficient amount to correct the errors.

The Merz demand-indicating apparatus consists of an attachment to an ordinary ampere-hour or watt-hour meter of the motor type. If attached to a watt-hour meter, the apparatus indicates the maximum number of watt-hours taken during a



142.—Mechanism of Merz Demand Indicator.

definite period, which is determined by a resetting mechanism worked by a clock. This resetting mechanism in no way interferes with the reading of the demand attachment, but only resets a wheel carrying a driving pin. Should the period between the times of resetting be one hour, the indicator reading is proportional to the maximum number of kilowatts taken during any one period of one hour since the previous reading and resetting by hand of the pointer to zero. The

apparatus integrates the load curve for each period of one hour, and the maximum value of these integrals is what is indicated by the pointer; consequently peaks of short duration are only taken account of to the extent that they help to swell the number of watt-hours taken during the period in which they occur. Fig. 142 illustrates the mechanism of this indicator. Its first wheel, A, is geared to a convenient wheel, B, of the meter train, and thus a spindle, D, is driven by means of the change wheels C. The spindle D carries and drives a sleeve upon which is fixed a ratchet wheel, G, worked by the paul H, and a pinion, X, which carries a driving pin, F. The pin F engages with another pin carried on a toothed disc mounted on the spindle carrying the pointer T. A pawl, P, holds the toothed disc, and, consequently, the pointer in the maximum position prevents its reading being altered at the times when the wheel X carrying the driving pin is set back to zero by means of the arm R and the quadrant rack Q.

This resetting arm R is worked by the cam K (rotated by the clock) and the spiral spring S. If the cam spindle makes one revolution per hour, R is released and sets X to the zero position once every hour. The change-wheel ratio is so chosen that at the full-load speed nearly one revolution of T would take place in the hour. The pointer is set to zero, after having been read, by releasing the pawl P and turning it back to the stop. As the cam is so placed that the arm R is ahead of the quadrant at full load, there is no friction introduced by the resetting mechanism.

CHAPTER VII.

TRAMCAR METERS.

With the rapid increase in the number of electric tramway systems, it is surprising that there are so few types of meters designed to record the energy supplied to the cars. The provision of a meter on each car is an excellent check on the motorman. For the measurement of the energy supplied to traction feeders no modification in the design of the ordinary switchboard-type meters is necessary so long as they are capable of measuring the consumption accurately with very fluctuating loads, but the conditions under which a meter erected on a car has to work are very different to those under which the ordinary house meter performs its task. The constant and violent vibration to which car meters are subjected would soon cause meters of the ordinary type to get entirely out of order. The nature of the load, also, is so very different. Meters on cars are not called upon to register very low loads, and, therefore, low-load accuracy, which is such an important factor in the case of meters for lighting circuits, can be neglected, but they require to be capable of registering accurately on, and carrying, overloads without sustaining any injury. The three types of car meters illustrated in Figs. 143, 144 and 145, are all modifications of ordinary meters of the same makes which have been previously described.

The Aron Car Meter.—In the Aron car meter, seen in Fig. 143 with its cover removed, it will be noticed that the axes of the main coils are horizontal instead of vertical, as in the ordinary meters of this make, and that the meter has only one moving shunt coil, which is carried by the spindle A. The clocks are controlled by balances instead of by pendulums, the rate of one of these is affected by the action of the main

current on the shunt coil, whilst the other works at a uniform speed, being controlled by its hairspring B.

In order to prevent registration on no load, or creeping, a coil C, which is wound oppositely to the main coils and through which the shunt current is passed, causes a slight backward torque to be exerted, which would cause the meter to register backwards on no load. This is prevented by a mechanical device in the shape of a pawl which prevents the recording train working in the backward direction.

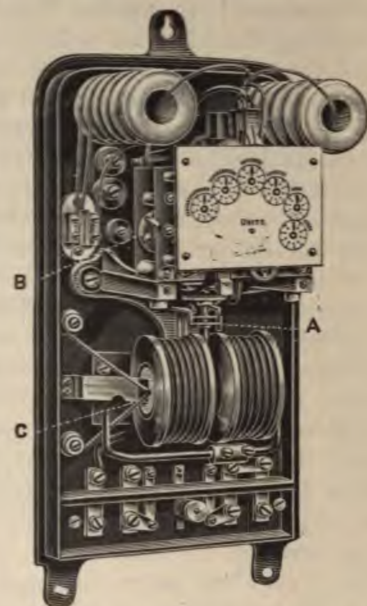


Fig. 143.—Aron Tramcar Meter.

The Bastian Car Meter.—The Bastian car meter is very similar to the ordinary Bastian meter. The only difference in the meter itself is that the level of the electrolyte at the zero mark is not so near the top of the tube, the zero mark being about 4 in. from the top. Being an ampere-hour meter, no account is taken of the pressure of the circuit. The case is slightly different in form, as will be seen from Fig. 144. It

consists of a cast-iron top with a copper sheath enclosing the tube. The meter is fixed by means of four screws, which pass through the top plate. This meter is made for 500-volt circuits and of 50-ampere capacity. The range of the index is 800 Board of Trade units, each division being equivalent to 5 units. The meter would probably require refilling about once a week, and, since this would necessitate frequent handling, it should for safety be connected into circuit on the earthed side at such

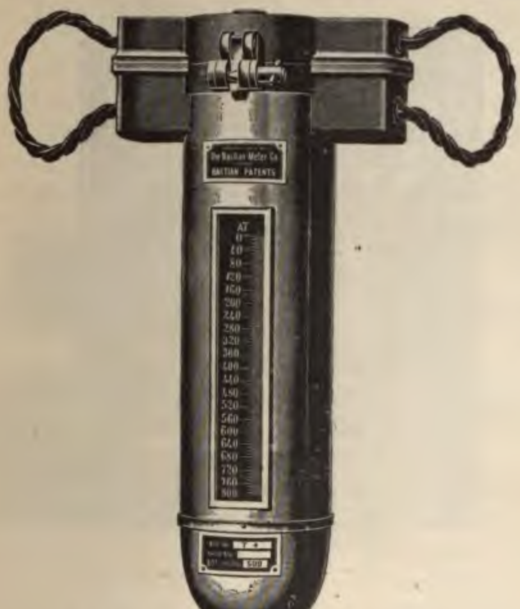


FIG. 144.—BASTIAN TRAMCAR METER.

a point that the lighting current does not pass through it. The length of the meter over all is 15 in.

The Thomson Car Meter.—The Thomson car meter is also a modification of the ordinary meter of this make, and an interior view of this meter is seen in Fig. 145. The chief points of difference between this meter and the ordinary meter

are in the weight of the moving system (which in this case is reduced to 88 grammes), the low resistance of the armature winding and the introduction of iron in the field to increase the torque, which is about 11 gr. cm. The moving system is supported by a spring-seated jewel which is designed to reduce breakage or roughening of the jewel to a minimum. The pivot is also removable.

Owing to the fact that low-load accuracy is not essential, the brush tension is made greater than usual, with a view to pre-

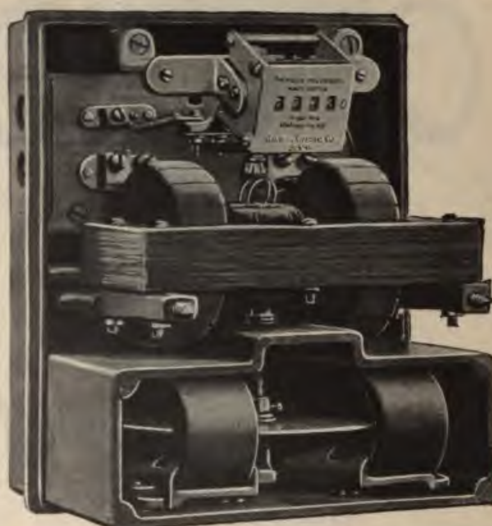


FIG. 145.—THOMSON TRAMCAR METER.

vent sparking, which would be caused by the large amount of vibration to which such meters are necessarily subjected in service.

The armature resistance is only about 30 ohms in this meter, and the armature has a resistance of 10,000 ohms in series with it. The drop from brush to brush, therefore, is only about 1·5 volts on a 500-volt circuit and the shunt current 0·05 ampere. The meters are made in sizes from 25 to 200 amperes at 500 volts and are constructed to stand heavy short-period overloads or an overload of 25 per cent. for several hours.

CHAPTER VIII.

CHOICE OF A TYPE OF METER.

The choice of a type of meter to be adopted is either the simplest or the most difficult task, according to the way the purchaser sets about it. To advertise for tenders for the supply of meters for 12 months, to find out the lowest price quoted, and to adopt the cheapest type, must be admitted to be a fairly easy operation. To decide on the type from the merits, even when samples are submitted, is by no means so simple. It then becomes a matter of experience and testing.

Experience is of great importance, as generally there is no time for a complete test to be made before a stock is required. The ordinary tests can be made quickly, but what are really required are long time tests, carried over several months, under actual working conditions. It is only thus that the majority of defects are discovered.

The nature of the supply, of course, reduces the number of types available to choose from, the meters suitable for both alternating and continuous-current circuits being placed in both lists. If several types prove equally accurate, and there is the same probability of their accuracy continuing, then it becomes simply a matter of cost and size. In towns, where often very little space is available for the erection of a meter on the consumer's premises, it is surprising what an important factor the size of a meter becomes. Frequently there is no room to fix a large meter, but just room enough for a smaller one.

Then noise must be thought of. Induction and clock meters are most usually the ones which are "noisy." Some induction meters emit a faint hum when the shunt circuit is connected to the supply. This hum may be imperceptible in the test room as in the daytime there is sure to be a certain amount of

noise, and this tends to drown the more insignificant sound caused by the meter, but it must be remembered that in nearly every case the shunt of the meter remains in circuit during the night, and a sound which would be unnoticed during the day becomes a very apparent one at night. The above remarks apply more particularly to flats than to other classes of buildings, the meters in flats having necessarily to be fixed near to the bedrooms. In this class of dwelling also it is sometimes difficult to find a solid wall on which to fix the meter; a lath-and-plaster partition forms a very good sounding board, and consequently magnifies the sound.

In clock meters the trouble is caused not so much by the ticking as the periodical noise due to the winding gear. Most clock meters are fitted with electrical winding gears. The makers have, however, striven to make them as silent as possible, and great improvement has been made in these devices of late.

To some the above points may seem trivial and their consideration unnecessary, but actual cases have occurred in practice where meters have had to be replaced by those of other types on account of complaints being made by consumers.

Among the many points which a good meter should possess the following are prominent:—

1. *Accuracy.*—Accuracy is most essential, and a meter should be accurate within a small percentage from the very lowest load to its maximum capacity, and even to an overload of 20 to 25 per cent. With small sizes it is possible to obtain this accuracy, as the smallest load is not so small a percentage of the full load. An 8 c.p. lamp may be assumed to be the smallest load on the great majority of meters on circuit, as it does not frequently happen that 5 c.p. lamps are so installed that each is controlled by a separate switch. With meters of large capacity the accuracy at the lowest load is seldom good. Even if they start registering when one or two lamps only are switched on, the inaccuracy is very great. A really good meter should have a "curve" which is a straight line starting from the lowest load.

2. *Permanence.*—The accuracy of the meter should remain permanent for a considerable period, and to attain permanence the following points are essential:—

(*a*) Minimum mechanical friction and consequently minimum compensation for mechanical friction.

(*b*) Permanence of brake. In a great many cases a Foucault brake is used. In this brake, as is well known, a disc of metal fixed to the moving portion of the meter runs between the poles of a "permanent" magnet or magnets. The motion of the disc in this field causes eddy currents to be set up in the disc, which cause a resistance to motion proportional to the velocity. The permanence of the magnets is, therefore, absolutely essential and depends upon the manufacture, ageing and design.

3. *Good Mechanical Construction.*—Upon the mechanical construction of a meter depends a great deal. A meter cannot be too well made, and often sufficient attention is not paid to this point by makers. This is principally noticeable in the recording gear. All meters, with the exception of electrolysis meters, are provided with wheel trains, for the purpose of recording the energy passed through the meter. If these wheel trains are not well made they are likely to have stiff places. This is one of the worst faults a meter can have, as it is one which is most difficult to detect.

The dials should be bold, as the readings often have to be taken in very imperfect light, or from a distance from the meter.

The arrangement of the case is also important. It should be absolutely damp-, insect- and dust-proof, and should be capable of being sealed efficiently on leaving the test room. There should be a "terminal box" or cover over the terminals, to enable the meter to be connected up on circuit without breaking the seals of the main cover. This terminal box should also be capable of being sealed after the mains are inserted in the terminals in order to prevent the meter from being cut out of circuit.

The case should be strong, and the whole mechanical construction should be such that it will allow the meter to stand a fair amount of rough usage without affecting its accuracy.

The arrangement of the terminal box is of importance. The mains should enter at the side or bottom, but not at the back. It should be easy to take out the mains without taking the meter down, in order that the standard instrument may be easily inserted when testing *in situ*. Meters as a rule are

erected by wiremen, and very probably are not too carefully handled between the time they leave the test room and when they are fixed in the consumers' premises.

Where a jewelled footstep bearing is employed, upon which rests the moving portion, convenient clamping gear should be provided to lift the moving portion off the jewel during transport. This clamping gear should be as simple as possible, and preferably it should be worked by the screwing up or unscrewing to a definite amount (made positive by a stop both ways) of a single screw.

4. *Small-voltage Drop and Shunt Current* and, 5, *High Torque.*—The drop in the main coils should be as low as possible, as this drop or fall of potential interferes with the regulation, being greatest at high load when the drop in the house wiring is at its worst. The drop varies with the size of the meter, being greatest in the smaller sizes, and diminishing as the ampere capacity increases, due to the fact that fewer turns are required in meters of large capacity to create a similar torque. The loss in the shunt circuit should also be small, but it by no means follows that the meter with the smallest shunt loss should have the preference. Assuming that the shunt watts are reduced at the expense of the torque, it may happen that the meter having the small current in its shunt has its torque to reduced that mechanical friction at very low loads will become important, and so alter the curve of the meter in this region. As a compensation, more compounding will be required to balance the friction, and under such conditions vibration—due to street traffic or other external cause—will have much greater effect, trouble being consequently given by the meter "creeping" or registering with no main current passing.

The shunt watt loss, in the case of meters having shunt circuits, does not seem to the writer to be nearly so important as it is usually considered. It is true that it is going on during the whole 24 hours, and that with many meters on circuit it adds up to a large number of units per annum; but it is a very difficult matter to estimate what these units actually cost. Certainly mains and station charges (exclusive of coal) do not enter into their cost, for the mains need not be any larger, and the shunt watts of meters cause no appreciable additional drop, even at maximum load. It is extremely probable that no more

coal is burnt to supply these watts than would be burnt if they were non-existent. When the station load is very light the slight load caused by the shunt watts certainly does no harm, and at full-load they form so small a percentage of the total output that they become insignificant. Now, the cutting down of the shunt watts in a meter also means, in a great many cases, the reduction of the torque. The more this is reduced the more important it becomes that the friction of the moving parts—be it solid or fluid—should remain constant. A slight variation of this friction has a greater effect if the torque is small than if it is large; the consequence is that at light loads an increase of the friction with time will cause a meter to under-register to a much greater extent than if the torque had been made large.

6. *Temperature Error.*—The accuracy of a good meter should be unaffected by variations of temperature. Most meters are affected by change of temperature to a certain extent; the smaller the temperature coefficient the better. Generally speaking, meters over-register at high and under-register at low temperature if calibrated at a mean temperature.

It is very advantageous that a meter should be capable of showing its working state. Motor meters possess this advantage. A window is usually fitted so that the main moving part can be seen without removing the case. This enables the meter reader to try the meter for starting by simply switching on one lamp. From the manner in which the meter starts and runs, a rough estimate can be made of its condition after some experience.

CHAPTER IX.

ARRANGEMENT OF A METER DEPARTMENT.

Considering the important part which meters play in the work of an electricity supply undertaking—the whole revenue being determined by them—it would seem that the provision of a convenient and well-fitted testing department should be of the greatest importance. This, however, is not always the case. Very often a room, badly lighted, in a corner of the station, for which no other use can be found, is the spot consigned for this work, quite apart from its suitability. The conditions which are necessarily imposed upon a meter cause it to be a delicate instrument, and railway travelling by goods train is a great ordeal to apparatus much stronger in construction than meters; consequently, the overhauling and testing of every meter is essential before it is fixed on consumer's premises.

Anyone who has had anything at all to do with making connections for electrical tests knows what a large amount of time is taken in preparation; and upon the planning out of the whole department the efficiency, or capability for turning out of work, depends in a great measure. It is impossible to lay down hard-and-fast rules, as the space available must differ in each case, but as far as possible it is advisable to arrange the various rooms in such a manner as to enable the meters to be got at easily, either for testing, repairing or cleaning, or for sending out on circuit. Care should be taken in the selection of a site which is quite free from vibration, either from the machinery of a station or from traffic in the road, otherwise it becomes very difficult to test at low loads. The rooms if possible should be rectangular and well supplied with daylight. The artificial lighting should be carried out carefully with a view to having

the apparatus under test well illuminated without trying the eyes of the tester. Cleanliness in a test room being essential, the design should be such as will enable this to be attained with the least possible trouble. The floors should be firm and clean. The best floor is one of concrete with parquet flooring over. Such a floor is easily kept clean, and forms an insulated flooring, which is very desirable, especially where high-pressure work has to be done.

As regards the warming of test rooms, this should be effected by means of electric radiators, hot water pipes, or some other form of clean heating appliance, but open fire grates should be avoided, as they are sure to be dirty.

The wiring is best carried out by running all leads in culverts round the walls of the room. These culverts may be iron troughs let into the floor with chequer plate covers in 4 ft. or 5 ft. lengths, flush with the floor. Both lead and return being run in the same iron trough prevents any inductive effect being felt by the testing instruments. The covers should be easily removable, when all leads are accessible, and any further leads, either temporary or permanent, can be put in; the general neatness of the rooms is in this way not affected by temporary or permanent additions. Where leads have to cross a doorway, a short length of pipe can be sunk in the floor and the mains drawn through. This also applies to other places, such as where the mains have to be brought to the test tables (*see* Fig. 146).

The arrangement of a testing department is shown in Fig. 146, from which it will be seen how the various rooms are arranged. In addition to the rooms shown, a yard on a level with the street is required, where the crates of meters delivered from the makers can be unloaded and unpacked. Here provision should be made for gently hoisting the crates from the carts. If the unpacking is done in the yard it avoids all litter getting into the testing department. The meters then pass the office on the way to the store, the numbers and other particulars being duly entered. Returned meters also come in in the same way, and when entered they also pass into the store.

It will be seen that the store is easily accessible either from the test rooms, repairing room, or office, and thus the carrying about of meters is minimised.

The routine is as follows: A batch of meters of a certain size are taken from the store, erected and connected up on one or other of the test tables. On the completion of the test they are taken into the repairing room for the purpose of being sealed up, when they again enter the store and are placed on the racks kept for "tested" meters, which are preferably those near the office. Meters as required can then be taken from the "tested" racks, in the order in which they have been tested, and sent out on circuit.

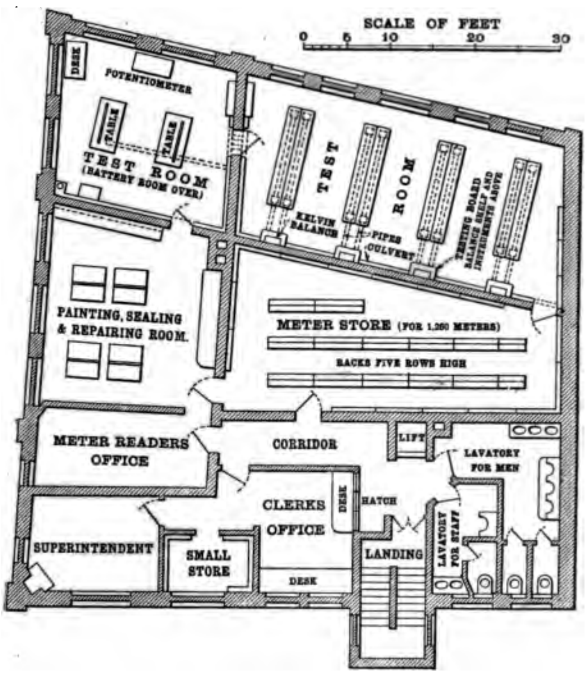


FIG. 146.—PLAN OF TESTING DEPARTMENT.

Wiring.—The system of wiring of the test rooms depends upon several things, such as the type of meters employed, the output of meters required, the nature of the supply current, and the pressure at which it is decided to supply the main current for testing. In all probability both watt-hour and ampere-hour meters are used. In alternating-current work

provision for the testing of watt-hour meters is sure to be necessary. In order that connections suitable for various tests may be made quickly, a connection board will be found a necessity. Such a board should be well made, as it will be in constant use. "Mercury-connection boards"—*i.e.*, blocks of wood covered with mercury wells, and in which combinations of connections are made by dipping ⊓-shaped pieces of copper into various wells—should be strictly avoided. Mercury can never be kept in its place.

A testing-circuit board designed by the Author, which has seen some years' service, is shown in Fig. 147 and diagram-

FIG. 147.—TESTING CIRCUITS BOARD.

matically in Fig. 148. As will be seen, it is entirely a plug board, the circuits being broken by switches on the testing tab'es themselves. It is designed for four complete testing circuits.

For small test rooms, with not more than that number it is extremely convenient. It is composed of four groups of main bars $1\frac{1}{2}$ in. by $\frac{1}{2}$ in. and two groups of shunt bars $\frac{3}{4}$ in. by $\frac{3}{8}$ in. Each group is composed of four vertical bars bolted on to the face of a marble slab 1 in. thick, and four horizontal bars bolted on to the slab at the back. Any vertical bar can be connected

to any horizontal bar in the group by means of plugs which fit tapered holes in the front bars and screw into the back bars.

The plugs for the small (shunt) bars are tapered where they make contact in both the front and back bars, and, in order that good contact may be made in both cases, a saw cut is run half-way up the plug, as shown in Fig. 149.

The connections are as follows: Each main circuit is split up into four parts, (1) supply, (2) standard instruments (Kelvin balance and ammeter in series), (3) resistance, and (4) testing tables.

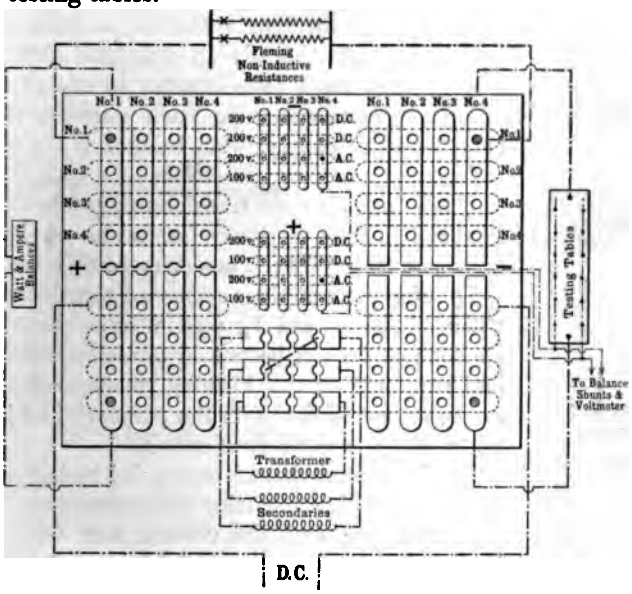


FIG. 148.—CONNECTION BOARD FOR TESTING CIRCUITS.

Referring to Fig. 148, the "supplies" are taken to the four lower main horizontal bars; the three lower ones are alternating current, each being supplied by a transformer. By suitable arrangements in the primary circuits of these transformers, all can be fed from the same circuit, or each can be supplied with current of different periodicity or any two can be connected one to each phase of a two or three-phase supply if necessary. The highest of the bottom group is fed with continuous current. To the left-hand vertical bars are connected the standard

instruments (watt and ampere balances), one to each bar. These bars allow of being short-circuited by means of plugs, thus short-circuiting the several balances. The top horizontal main bars are connected to several Fleming non-inductive resistances, and between the right-hand vertical main bars the testing tables are inserted.

In Fig. 148 only one of each of the circuits is shown wired, the others all being similar. Although any table can be put on any current with either balance and either resistance in-circuit for ordinary testing, yet the plugging remains simple, for the plugs always form the four corners of an imaginary rectangular figure. To make this clear, a completed circuit is made up, assuming plugs have been inserted in the shaded holes (Fig. 148). In this example, table No. 4 is connected up to alternating supply, with balance No. 1 and resistance frame No. 1 in circuit.

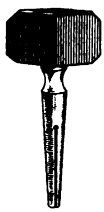


FIG. 149. PLUG FOR SHUNT BARS.

If required, all these transformers can be paralleled and all three resistance frames also paralleled on to one table through one or more balances.

By using pairs of plugs connected together with "flex," balances can be put in series for comparison; tables can be put in series for runs for dial readings; or the Fleming resistance frames can be cut out of circuit for the purpose of subjecting meters to a dead short-circuit.

The horizontal shunt bars are fed as indicated (Fig. 148) with alternating and continuous current at different voltages; and the vertical bars feed the various table and balance shunt leads, care being taken that no appreciable drop takes place between the table and the balance. In Fig. 148 the table shunts would be fed with 200 volts alternating if the plugs be inserted in the blackened holes.

The main circuits are at 100 volts, aud it has been found a great convenience to test on this pressure. Several meters can be connected up in series and still be tested on a power factor very nearly approaching unity; moreover, the shunts are fed from the same transformer. In the case of 200 volt meters, the two top transformers are connected in series by means of plugs and cords, as shown by the dotted line in

Fig. 148, leaving the bottom transformers capable of being paralleled if necessary.

These circuits are, however, not used above 100 amperes, the great majority of supply meters having a much lower amperage. Larger meters, up to 2,000 amperes capacity, are tested on a special circuit not connected to the board.

Such an arrangement of the testing circuits as the one just described is rather extravagant in wiring unless the board is

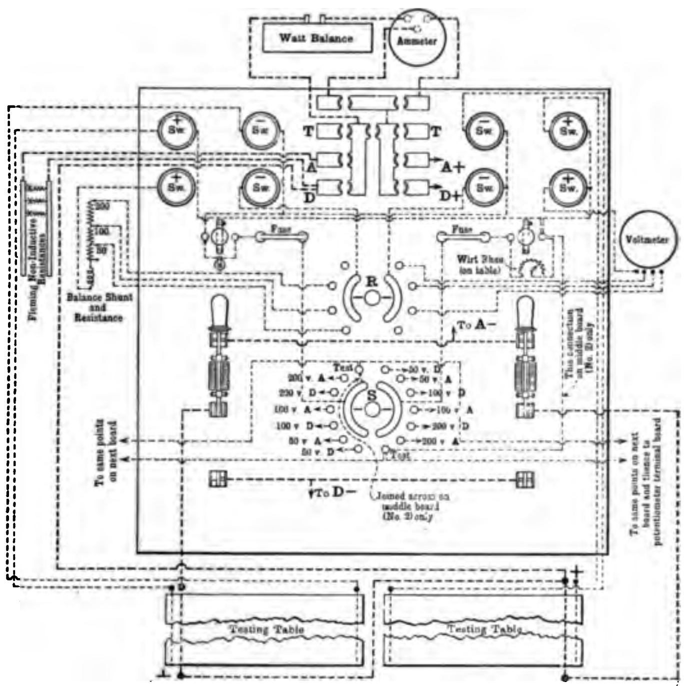


FIG. 150.—WIRING OF TABLE BOARDS.

in a fairly central position, but the advantage of being able to make so many combinations is very considerable.

For larger test rooms, where the testing can be specialised, and where there is enough work to always keep certain tables or testing racks occupied with meters up to a definite size, a simpler method of wiring is that shown in diagrams 150 and 151. In this arrangement—which with its boards the Author

designed for the Metropolitan Electric Supply Co.'s testing department—the various test tables have their own standard instruments, resistances and switchboards, each set being independent of the others.

Taking the main-current circuits first, and starting at the plug bars at the top (Fig. 150), alternating current is taken to the lowest bar but one on the right, A +, and continuous current to the lowest, D +. The top plug bars are for inserting one or other of the ammeter coils. It is convenient to provide double-range ammeters, the one range 10 times that of the other. If this portion of the wiring be traced, it will be seen that a plug inserted in the right-hand top hole puts the

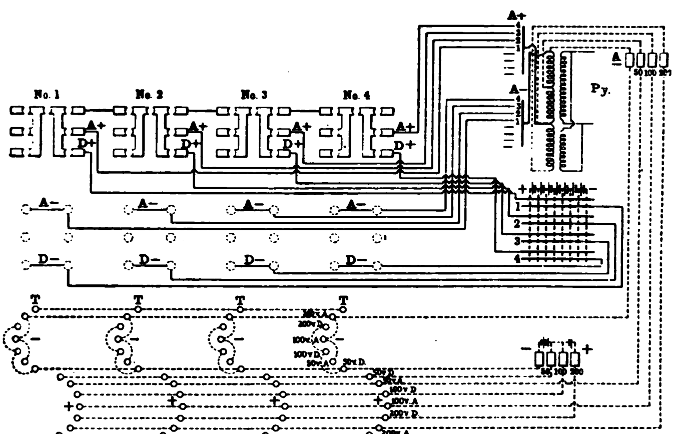


FIG. 151.—GENERAL ARRANGEMENT OF WIRING TO TABLE BOARDS.

high-range ammeter coil in circuit, whilst simply removing the plug to the other upper hole connects up the low-range coil of the ammeter. It may here be mentioned that in alternating-current work ammeter coils must not be short-circuited, otherwise the readings will be upset owing to the transformer action of the one coil on the other. Assuming the plug is in A + and the corresponding hole A (on the left), the circuit would be as follows: Alternating current would pass from A + through one or other of the ammeter coils (according to the position of the ammeter plug) and the Kelvin-Watt balance to A, then through the Fleming non-inductive resistance to the test table

terminals +, through one or the other or both sets of meters on the two "half" tables, and thence to the mid point of one or the other of the two throw-over switches. The switch being on to the top contact, the current returns to A –.

For continuous current the plugs would be taken out of A +, A, and put into D +, D, and one or the other of the switches put to the down position, from which the current returns to the negative pole.

The continuous current is taken from a battery at low voltage; thus the Fleming resistance is not required, and consequently is left out of circuit when on continuous current. In both cases the current is regulated by means of a carbon rheostat placed in a handy position at the table.

The blocks, marked T, of the plug bars are for comparing the standard instruments, and will be explained later.

The pressure circuits are arranged thus: Current at various voltages—alternating and continuous—is supplied to the right-hand segments of the lower double-pole volt switch S, and leaves at the left-hand segments of this switch.

According to the position of the switch, its bars are charged with the different currents and pressures. The right-hand bar is connected through a fuse to a Wirt rheostat with a short-circuiting switch (the rheostat being on the table). Here it splits up, passing through switches to (1) the shunt-circuits of either table, (2) voltmeter, (3) balance shunt. (1) Passing through the meter shunts it returns to the other table switches. (2 and 3) Passing through voltmeter and balance shunt coils and their extra resistances to the upper volt switch R (according to the position of the switch which is set for the voltage required), and thence to the other balance and voltmeter switches. All these circuits then become common as at starting, and the current returns through the left-hand short-circuiting switch and fuse to the left-hand bar of S and back to the supply.

It will be noticed that the left-hand short-circuiting switch is used for short-circuiting a lamp, which is a 200 volt 16 c.p. or 32 c.p. one. When testing, the lamp is, of course, short-circuited.

This lamp is used as a preventative for the fuses blowing should there be a short in any of the meters on test. Secondly,

it has been found very convenient for burning out a leak to spindle such as may occur in a commutator meter due to silver dust, or for locating other leaks to case without causing the blowing of fuses. In these cases one pole of the shunt circuit is connected to the meter case and the other to the meter shunt or main terminal, as the case may be.

Fig. 151 shows the connections from the table board to the sources of supply. For simplicity the right-hand half of the volt switch S (Fig. 150) has been lowered. Below the plug bars are the two main throw-over switches. The main alternating leads go to two 'bus bars through fuses. The main continuous current leads go to a plug board shown diagrammatically, which enables various numbers of cells to be used in series, according to the drop through the meters under test. The pressure circuits go to single-pole cut-outs (one on each pole), and thence to the transformers or to the small secondary battery, as the case may be.

Referring to the testing bars T, these are provided for the purpose of easily connecting up one or more of the standard instruments for checking their accuracy. In the case of Watt balances and voltmeters it will be noticed that the end segments of the supply volt switch (S, Fig. 150) are marked "TEST."

The use of the testing bars is shown in Fig. 152. In this diagram five complete "sets" are shown, three being watt-testing circuits (Nos. 1, 2 and 3) and two (Nos. 4 and 5) ampere-testing circuits, which, therefore, have no shunt or potential switching apparatus.

The main connections for the comparison of the standard instruments are simple enough, but in the case of the shunt connections it is necessary that one of the supply volt switches be connected up in a slightly different way to the others; this is to enable the standard instruments being compared to be supplied with current from the existing sources.

It is advisable to make the middle set of three the specially connected one, for this reason: That the one on either side can be compared with it without interfering with the remaining one and this in no way hinders all the sets being connected up for comparison. The special connections referred to above are (1) the top left-hand segment of the switch S (Figs. 150 and 152) is permanently connected to the left-hand bar of that switch as

shown; (2) the bottom right-hand segment is connected so that the Wirt rheostat of that set is in circuit with all the shunt circuits as shown.

In Fig. 152 plugs are supposed to be inserted in the blackened holes. No. 1 table is free for the testing of meters. Nos. 2 and 3 (watt circuits) are connected up for comparison of standard instruments and ammeters and voltmeters on 200 volts alternating, whilst Nos. 4 and 5 (ampere circuits) are arranged for comparison on continuous current, and a standard potentiometer shunt, P, is included in the circuit on the right-hand table (No. 4).

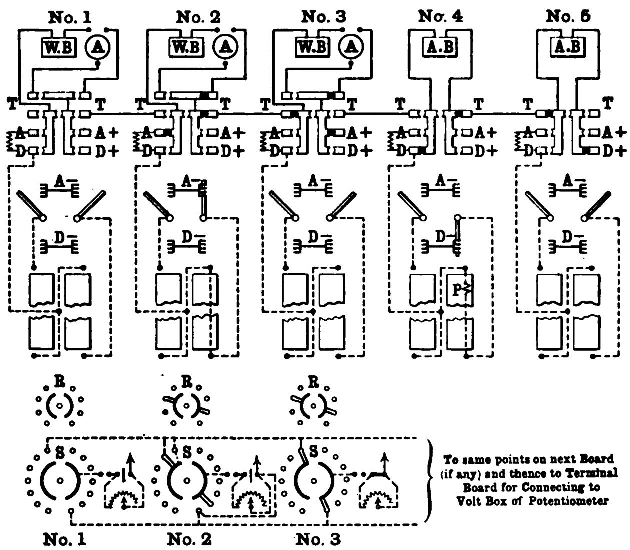


FIG. 152.—DIAGRAM OF CIRCUITS SHOWING USE OF "TEST" CIRCUITS IN COMPARING STANDARD INSTRUMENTS.

The object of the Wirt rheostat short-circuiting switches is seen in the diagram. If the Wirt rheostat on table No. 3 were not shorted when comparing the standard instruments, there would be additional resistance in the volt circuit of the instruments of that set, which would cause those instruments to read low. It may be mentioned that single plugs are used only when comparing the standard instruments. For ordinary

work, plugs braced together as in Fig. 153 are employed, which prevent the insertion of the plugs in the wrong holes—*i.e.*, one on to alternating current and the other on to continuous current.

It will be noticed that to each board there are two tables (*see* Figs. 150 and 152). The object of this is that, while meters are being tested on the one table, the meters just finished on the other may be taken down and a fresh set connected up. It is advisable to have the two tables rather than one double the width in order that the vibration caused in taking down and putting up meters on the idle one may not interfere with the testing on the other. The two can, nevertheless, be used as one if required.

The advantage of such a system of connections is that, as the board is placed under the balance shelf and immediately oppo-

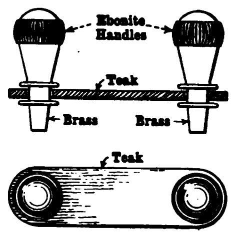


FIG. 153.—BRACED PLUGS

site the ends of the table (*see* Fig. 155), the changes are quickly and easily made, without having to build the circuit up at a central plug board, as in the previously described arrangement of wiring. The instruments, being opposite the ends of the tables, are conveniently situated for being seen from any point along each table; it is thus possible to keep an eye on the current while testing. This avoids the necessity of having two people on the same test, one to regulate and the other to count the revolutions of the meter's moving part. Fig. 154 is a view of a testing panel with the instruments above it. Between the panel and the balance shelf a teak locker is provided for the purpose of storing the balance weights, plugs, &c. A porcelain tube let into the wall between the testing panel and the instrument panel contains the necessary leads between the two.

The watt balance resistance box can be stood above the instrument panel, as seen in Fig. 155.

It must be borne in mind that the testing of meters is not usually, if ever, the sole work carried out by a testing department. All the station instruments require periodic

FIG. 154.—TESTING PANEL AND ARRANGEMENT OF INSTRUMENTS.

standardising, and this work becomes considerable in a large undertaking. In fact, all the electrical testing is, or should be, performed by such a department. In the design, therefore, provision should be made for work other than meter testing.

Separate rooms should, however, be allotted to other work, such as motor, arc and incandescent lamp testing, fuse blowing, and the breaking down of insulators with extra high pressure. The latter work, which is frequently required by users of extra high-tension currents, becomes dangerous if carried out where other work is going on, whilst the former all hinder meter testing by noise or light as the case may be. The equipment of such test rooms does not, however, come within the scope of the present chapter.

FIG. 155.—VIEW OF A TEST ROOM.

Testing Tables, Meter Stands, Testing Racks.—In considering the design of meter-testing tables, it must be remembered that several types of meters are sure to be used. As no two types are similar in size, shape, or arrangement of fixing lugs, the difficulty presents itself of getting the same table or rack to be suitable for the different types employed—and, even more than this, for any future type that may be adopted later. Fortunately, meters of different types which are being brought out at the present day are becoming more nearly alike in outward form than were the differing types of some years back. For instance, most of the newest meters are designed to hang up

and, more often than not, are provided with a central lug at the top to enable the meter to be hung on a screw previously fixed to the meter board.

Meters possessing this central lug are certainly the easiest to fix, both in the test room and on consumers' premises. There are, however, some meters which stand level, such as the

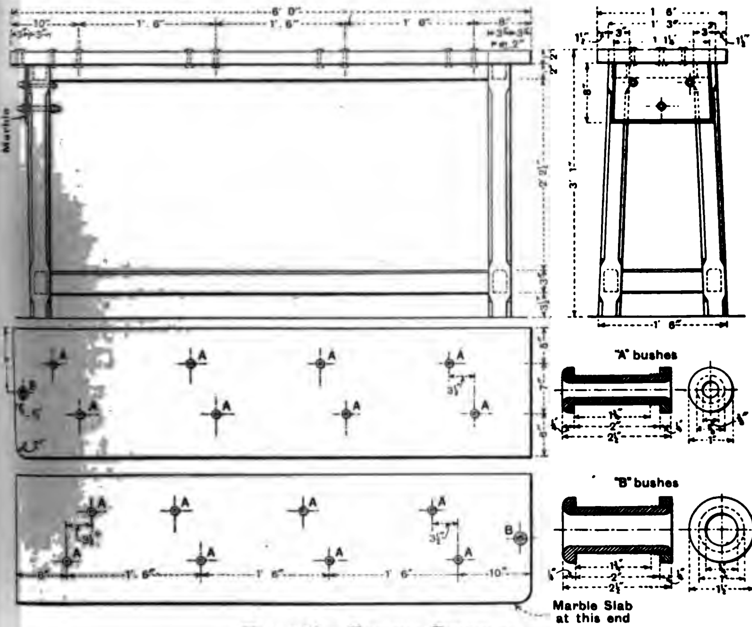


FIG. 156.—TESTING BENCHES.

Ferranti (A. and C.C.), Hookham (A. and C.C.), Reason, Mordey-Fricker, &c. For such, therefore, a table is all that is required, and, on account of meters of some makes standing, it is necessary that the table tops should be capable of being used. In other words, they should not have anything on them in the shape of a fixed rack for "hang up" meters, which would get in the way when meters are being tested, which stand on a horizontal surface. The table should be substantial, for some meters are heavy, and a set of such meters becomes a fair load.

A simple form of table which has been found to answer its purpose is shown in the dimensioned sketch Fig. 156, and is

made of teak, the top being 1 ft. 6 in. wide by 2 in. thick. The length may be 6 ft., but similar tables have been made 10 ft. long, with a pair of legs in the middle. It is preferable for steadiness to have two shorter ones as shown, for a six-legged table requires to be nicely adjusted to the floor unless the ends of the legs are grouted into the cement, which is a good plan. The legs in the sketch are 3 in. by 3 in., and the bars 3 in. by 2 in. Holes are fitted with brass bushes for the purpose of bringing the shunt leads up to the meters, their positions being such that they escape the stands used on such a table, which will be presently described.

These shunt leads are teed-off leads, which run from end to end of the tables, well apart, cleated to the underneath of the table top at each point, the tee also being cleated by the same cleat to take any strain off the joint. The leads, which are single flexibles, pass round through weighted pulleys similar to telephone cords, and through the bushed holes in the table. Their ends are soldered into terminals suitable for connecting to the ends of the shunts of the meters. These terminals are shown in Fig. 157, *a* being used for the front leads which enter the small terminal of the meter and *b* for the back leads which are connected to the end of the meter shunt, which is usually common to the main, but is removed for testing. The terminals cannot pass through the bushes in the table, and immediately they are disconnected from the meter they fly down and thus prevent shorts, but are always handy and quickly connected up.

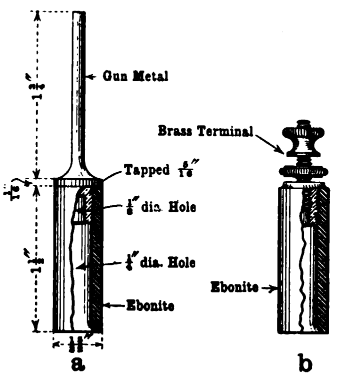


FIG. 157.—SHUNT TERMINALS.

Such an arrangement of the shunt leads seems preferable to having plugs on the leads to fit into bases at intervals along the table, as plugs are apt to make bad or intermittent contact after a time unless well made, and if of porcelain stand a good chance of being frequently broken.

A better form of testing bench is that illustrated in the two elevations in Fig. 158 and in the view of a test room Fig. 155. This bench consists of two 4 in. by 4 in. uprights supported on foot pieces of the same dimensions and braced together by 3 in. by 2 in. cross-bars. Rigidity is obtained by using angle brackets, and the table top is supported by the upper cross-bars and on brackets at the uprights. Above the table top the uprights extend 2 ft., and are bored at 2 in. intervals, the holes being fitted with brass tubes, which are expanded back and front. Two cross-bars are provided for each table and can be bolted to the uprights at any required distance apart. The cross-piece being 3 in. deep and the spacing of the holes in

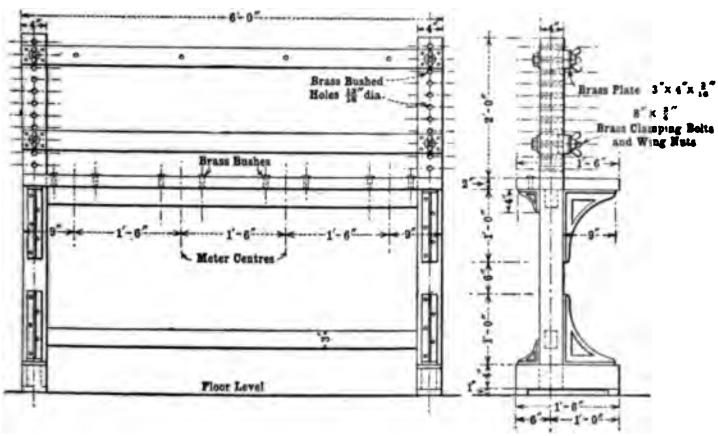


FIG. 158.—ADJUSTABLE METER-TESTING BENCH.

the uprights 2 in. from centre to centre, their distance apart can be made suitable for any meter not longer than 2 ft. A polished brass plate, 3 in. by 4 in., screwed to the cross-pieces at each end, not only gives them a finish, but prevents wear by the screwing up of the wing nuts each time the position of the cross-pieces is altered.

Round-headed screws placed at intervals along the upper cross-piece form sufficient support for hanging meters, the bottoms of which rest against the bottom cross-piece. A 6 ft. table, as illustrated, will carry four meters giving a spacing of 1 ft. 6 in. between meter centres, which in practice has been

found to be a suitable distance. Meters should not be placed nearer to one another than this, even if their external dimensions allow of it, in order that they may not be affected by the meters on either side. With some meters, such as the old-type Thomson, the upper cross-piece is placed behind the uprights, the meter standing on the lower one, being clamped to the upper one. Standing meters can also be supported by the cross-pieces in the same manner, so that these tables possess the advantage of holding any type of meter, including switchboard-type meters having long projecting terminals at their backs for passing through the panels, and still keep the table top clear for tools, notebooks, &c. The cross-bars, not being fixtures, can be removed altogether at a moment's notice, leaving a plain table with no obstructions above it.

Fig. 155 is a view of a test room furnished with tables of this type, and local testing panels as previously described. In this figure the arrangement of shunt cords is also seen, and it will be noticed that different types of meters are being tested on each table.

Testing Stands.—Where plain tables are provided, some form of testing stand will be necessary. A very useful form of stand for holding meters when being tested is shown in Fig. 159 in front and side view. A stand somewhat similar to the one illustrated was used some years ago by the British Thomson-Houston Co. for the Thomson meter, and the one illustrated is also used for that type. In Fig. 95, p. 121, a meter of this make may be seen supported on one of these stands. This meter in the old type is a rather awkward one to erect temporarily unless it is screwed up to a batten fixed to a wall, in which case the continual insertion of screws would soon make it necessary to have a new batten. On the stands, however, it is easily fixed. The weight of the meter is taken by the two brass brackets on which the terminal box rests, whilst the milled-head screw in the brass angle-piece to the left clamps one of the top lugs of the meter. To make the meter firmer on the stand, the right-hand lug is also clamped by means of the loose clamp shown. To the back of the stand a batten is fixed vertically by means of sash screws, so that it is easily detachable. On this batten at a suitable height is a headless

nail, slightly bent up, upon which "hanging" meters are hung.

The stands are made of teak, the base being 1½ in. thick, 12 in. deep and 12 in. wide, the back 1 in. thick, 13 in. high from the top of the base; the batten is 2 in. deep by 2½ in. wide by 19 in. long, and stands 12 in. above the top of the back.

The stand—resting on three points, two in front and one in the centre behind—is always firm on the table, and can be levelled by means of the milled-head screw at the back. If countersinks are let in flush in the table top, the stands are kept in a line, and the weight of the stand and meter prevents side slipping if any slight adjustment of the meter is required.

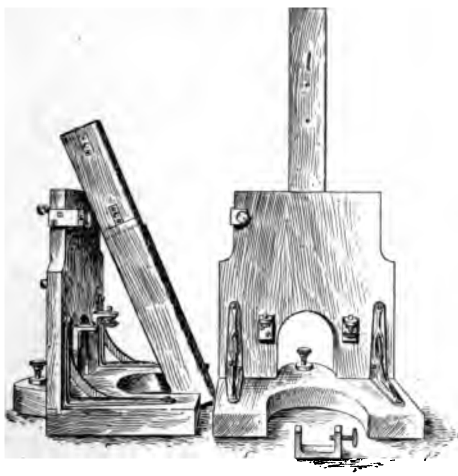


FIG. 159.—STANDS FOR SUPPORTING METERS WHEN TESTING.

These stands will hold most types of meter. They have been found equally suitable, without any special fixing for meters of the following types:—Aron, Bat, Bastian, Brush Gutman, Eclipse (all types), Electrical Company's (all types), "O.K." (including prepayment), Scheeffer, Shallenberger, Shuckert, Stanley, Thomson (all types), Vulcan, Westinghouse, Wright, &c.

A further advantage possessed by such stands is that they enable a set of meters of different types to be erected in series if required for the purpose of comparison under absolutely similar conditions of current.

Fig. 160 shows a table and set of stands, each holding a different type of meter. This view also shows the shunt leads already referred to in use; also the position of the Kelvin balance at the end of the table with magnifying glass for reading the index from any point along the table. Fig. 161 is another view of the same table, the stands being removed and a set of "standing" meters connected up for a "long run" test.

These stands may also be used for ammeters and voltmeters, making a most convenient support for such instruments. The ordinary switchboard ammeters which are provided with back

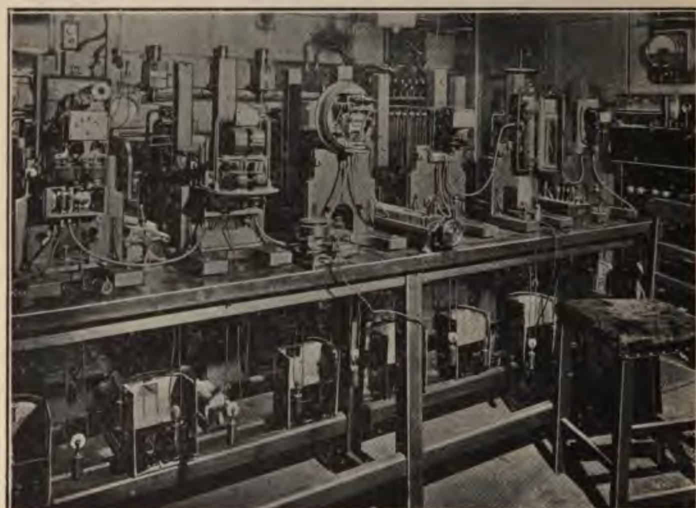


FIG. 160.—TEST TABLE WITH STANDS, SHOWING THE ADAPTABILITY OF THE STANDS TO DIFFERENT TYPES OF METERS; ALSO THE POSITION OF KELVIN-WATT BALANCE AND REGULATING RHEOSTATS.

connections in the shape of rods are somewhat awkward to fix, but with the stand, the rods either go through the hole in the stand-back, or, if too wide apart for that, they most probably clear the batten and can thus be fixed to it.

Meter Store.—As with the test tables and supports for meters in the test room it is important to provide suitable appliances for use with many and varied types of meters, so it is equally

important in the store to provide racks for storing meters of many shapes.

Hanging meters—*i.e.*, those which have a central top lug, may be conveniently stored by simply having horizontal battens fixed to upright ones firmly fixed to the walls and fixing screws (round-headed for preference) at certain distances apart on the horizontal battens, the screws being screwed "half-home." For the centre of the store frames running the length of the room and carrying similar battens could be used. There are, however, several objections to such an arrangement. In the

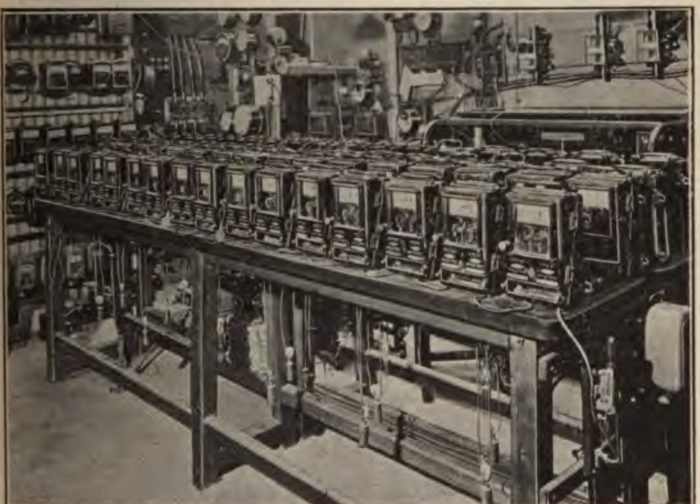


FIG. 161.—TEST TABLE WITH STANDS REMOVED FOR A SET OF "STANDING" METERS ON A "LONG RUN" TEST.

first place many meters are not provided with the central lug, and even with those which have it, the spacing sideways and the vertical distance apart of the battens becomes a difficult matter to settle owing to the varying sizes of the meters. To make matters worse, it would be found that the lugs of the meters would have varying-sized holes, so that it would be impossible to choose a screw which would suit all, if indeed one could be found to suit any two.

For storing on battens as above, it is necessary for the meters to be provided with a shaped hole, as otherwise the lug would not slip over the head of the screw. Such a system, therefore, is only suitable for very few types. It is, however, a convenient one to use with Bastian and Wright electrolytic meters, and Wright demand indicators. If, instead of using wood, iron be employed, the system becomes far preferable from a fire point of view.

Shelves are not altogether convenient for the storing of meters, owing to the fact that so many types do not stand, and would require to be laid on their backs. The storing of meters

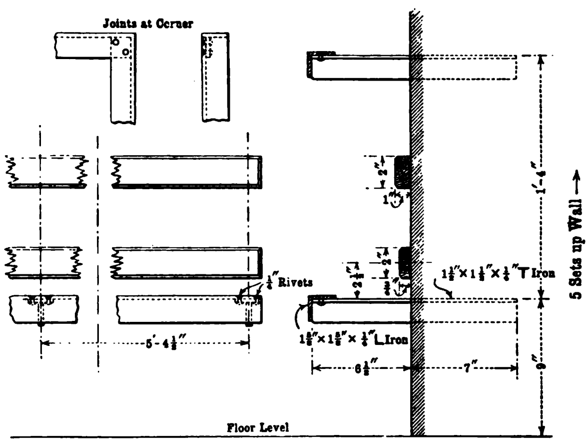


FIG. 162.—WALL RACKS IN METER STORE.

on their backs is a thing to be avoided, as when so laid it becomes very difficult to see the dials, numbers, &c.

A modified form of shelf rack, which has been found universal, is shown in Figs. 162 and 163. These racks were designed by the writer some years ago, and have been found to answer the purpose well.

The wall racks (Fig. 162) are extremely simple. A tee iron, $1\frac{1}{2}$ in. by $1\frac{1}{2}$ in. by $\frac{1}{4}$ in., is let into the walls at intervals of 5 ft. $4\frac{1}{2}$ in., and an angle iron $1\frac{5}{8}$ in. by $1\frac{5}{8}$ in. by $\frac{1}{4}$ in. is laid along on the ends of the tee irons, and flush riveted to them. Along the wall, as shown in the drawing, are fixed battens of

wood to protect the wall from being chipped by the meters when placed on the racks.

The centre double racks (Fig. 163) are very similar as to dimensions, but, instead of tee iron, flat iron is used for the supports of the angle irons, which are of the same size as in the wall racks. H-iron girders, 2 in. by 2 in. by ¼ in., extend from floor to ceiling 5 ft. 5 in. apart, and are, if possible, bolted by angle pieces to the floor girders top and bottom. To these are riveted the brackets formed by the flat-iron strips. Flat strips braced at intervals are riveted to the H-iron supports and take

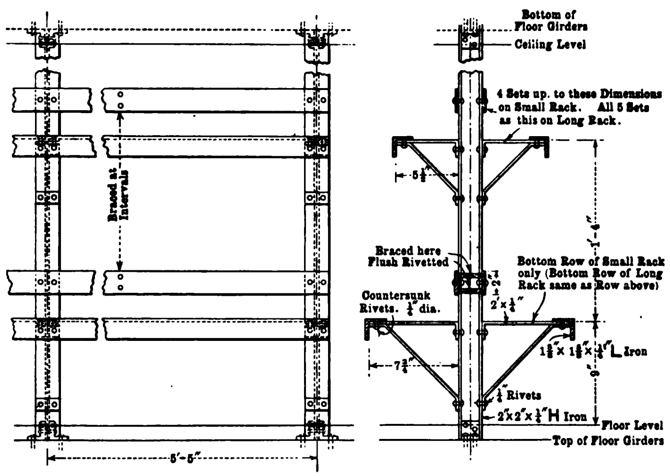


FIG. 163.—DOUBLE RACKS IN METER STORE.

the place of the wooden battens in the wall racks. A distance of 1 ft. 4 in. has been found convenient between tiers; this makes the top tier of five, 6 ft. 1 in. from the ground, if the lowest rack is 9 in. above the floor level; it is, therefore, possible for an average-sized man to put meters on the top rack without the aid of steps. It might be thought that the above-described racks are rather costly, but it may be argued in their favour that they are capable of standing the unavoidable knocking about which they get by repeated loading and unloading. They are fire-proof, and being equally suitable for all types of meters they have little chance of standing idle.

They are also independent of the "width" of the meters, and allow narrow meters to be bunched closer together than wide ones so that no space is lost.

Small Store.—For the storing of spare parts of meters, wire, backing boards, and other sundries, it is very necessary to provide a small room, or a large cupboard fitted with wide shelves. This apartment should be adjoining the office, as it then becomes quite easy both to keep the costs of repairs, and a check on the stock of these sundries. This store should be provided with as many shelves as it is convenient to place in it.

CHAPTER X.

INSTRUMENTS, APPARATUS AND ACCESSORIES.

Equally important as the convenience and arrangement of the test rooms is the provision of accurate standard instruments, which, however, should not be kept simply for the checking of other instruments, but should be used constantly, and every meter should be compared with them.

Kelvin Balances.—The watt and ampere balances invented by Lord Kelvin are, perhaps, the most suitable instruments for the purpose. They are simple, constant, and it is possible to ascertain by observation if they are in working order. When in this condition, their accuracy depends simply on the constancy of weights, and this is a great point in their favour, as the weight of a mass is a constant, whereas one can never be certain that a spring has not changed (except by re-standardising). Meters, as a rule, are tested at a round number of amperes, consequently no recourse has to be made to the table of doubled square roots provided with the ampere balances, as the weights are set to definite points on the fixed scale. These instruments are founded on the law, first discovered by Ampère, that if a current flow through two conductors near one another, one fixed and the other movable, a force is produced tending to attract or repel the movable conductor. This force is proportional to the square of the current. The balances (in the smaller sizes of Kelvin balances) are provided with four fixed and two movable coils, the latter supported by a beam which is suspended by means of a flexible ligament. This suspension is composed of a great number of very fine wires in two groups insulated from one another, and the current to and from the

movable coils is conveyed through these groups of fine wires. A centi-ampere balance is seen in Fig. 164, and Fig. 165 represents a section through the coils; FF are the fixed, MM the movable coils; A one of the groups of fine wires which act as the fulcrum. The arrows show the direction of the current in the coils.

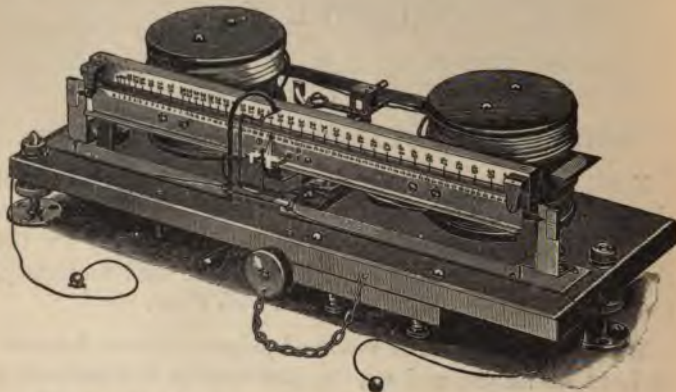


FIG. 164.—KELVIN CENTI-AMPERE BALANCE (cover removed).

Parallel currents in the same direction attract, and in opposite direction repel; it will therefore be evident that the right hand end of the beam will be raised out of its position when a current flows through the coils in the directions indicated

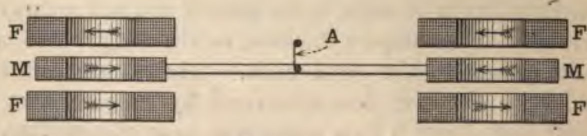


FIG. 165.—SECTION THROUGH COILS OF KELVIN BALANCE.

in Fig. 165. As the midway position between the two fixed coils is the position of minimum force, the movable coils are hung, the one above and the other below the mid position, being nearer the repelling coil in each case by such a distance as to give about one-fifth per cent. more than the minimum force.

The beam carrying the movable coils being deflected out of its zero position by the force due to the current, is brought back to its original position by a force due to a weight, which is slid along on a platform fixed to the beam until balance is obtained (*see* Fig. 164). The beam is graduated, and the weight (which also acts as a sledge for carrying other weights) has an index on the scale and is read when balance is obtained. At each end of this movable graduated scale is a pointer which indicates the zero position. Both these pointers should be at zero before commencing to measure current. They are brought to zero by bringing the sliding weight to its zero and then shifting the position of a metal flag (attached to the movable portion) by means of the handle provided. Each sliding weight has a counterpoise weight which must be used with it. The latter is placed in a V-shaped pan at the right hand end of the movable portion (*see* Fig. 164). Four pairs of weights are usually provided, being adjusted in the ratios of 1 : 4 : 16 : 64. Each pair gives a round number of amperes or fractions or multiples of amperes (according to the size of the instrument) on another scale, which is fixed to the base of the instrument just behind and above the movable scale. The numbers on this fixed scale are twice the square roots of the numbers below them on the movable scale. Notches are cut in the edge of the movable scale just under the numbered divisions on the fixed scale to avoid errors due to parallax when reading. The sliding of the weight to the correct position along the scale is performed from outside the case by means of a self-releasing pendant carried on a sliding platform to which silk cords are attached which come out through the ends of the case. By using a magnifying glass (a reading glass acts perfectly) with an aluminium screen attached, as in Fig. 166, the index can be quite easily seen 12 ft. or 14 ft. from the balance. The screen, which should be lamp-blacked on the side away from the balance, causes the index to be seen at a glance and hides all reflections from the balance case. Mounted on a stand in the way shown in the figure, the hole A drilled up the handle—a medium tight fit—it can be raised or lowered to the correct position.

Great care should be taken that, once being set to a definite position, the weight of the Kelvin balance is not accidentally

shifted. At the ends of the silk cords which are attached to the sliding platform are usually two buttons. If one of these falls off the shelf on which the balance stands, or if anyone passes and rubs up against the cord, the weight is liable to be shifted. To prevent this a good plan is to replace the two cords by one which is brought from the sliding platform through the case in the ordinary way, through two pulleys fixed to the shelf—one under each end of the base where the cords come out—back through the case at the other end and thence to the sliding platform. In this way, no matter what the position of the sliding weight, there is no slack cord.

Fig. 166.—Magnifying Glass with Screen for use with Kelvin Balance.

The watt balances are very similar to the ampere balances. The shunt current is taken into the movable coils, and the main current passes through the fixed ones. The resistance of the shunt coils is about 14 ohms, and as they are designed to work with a current of 0·2 ampere in the shunt circuit, the total resistance is made up to 500 ohms (non-inductive) per 100 volts.

The shunt circuit, even on 100 volts, therefore, is fairly non-inductive, but, of course, becomes more so on higher voltages. Where meters are required for both alternating and continuous-current supplies it much simplifies matters to have standard instruments equally suitable for both kinds of current; these balances being so, they are most convenient.

Voltmeters.—A number of voltmeters should be provided of different types and different ranges. A set of electrostatic voltmeters for different voltages is very useful, especially for use when taking shunt currents of meters. Owing to the fact that they take practically no current, they can be connected directly to the ends of the meter shunt circuit and the pressure ascertained at which the shunt current is measured. Hot-

wire or electro-magnetic voltmeters could not as conveniently be used thus, for the current they take would be measured as well as the shunt current of the meter.

If the ammeter be placed between one terminal of the voltmeter and the meter shunt, the drop in the ammeter would have to be allowed for.

Another point in favour of electrostatic voltmeters is that the same instrument can be used as a standard both on alternating and continuous current. (Two readings, with connections reversed, must be taken on continuous-current circuits.) They are very handy for calibrating or checking other alternating-current voltmeters. As a standard voltmeter, a reflecting electrostatic voltmeter with a scale forming an arc of a circle of one metre radius is recommended. The instrument and scale should both be fixed in position, and preferably the scale should only be calibrated, by means of a potentiometer, after it has been put up.

Potentiometer.—For standardising generally (on continuous current), and indeed for testing continuous-current ampere-hour meters, a good potentiometer is extremely useful. If at any time doubt as to the accuracy of the standard instruments arises, as it is sure to do at some time or other, possibly owing to a batch of meters all being found about the same amount slow or fast, then to be able to check the instruments with some quite different apparatus is desirable.

The potentiometer enables current, pressure and resistance to be measured with great accuracy, and all measurements are compared to the E.M.F. of a standard cell, usually a Clark.

Space does not permit of a detailed description of this universal instrument, with its accessory standard resistances, but a brief description of the general principle of its working may, however, be useful to those who may not be acquainted with it.*

The instrument itself consists of a set of resistances, all of the same material and section, which are arranged as shown in Fig. 167. In the Crompton pattern there are 15, in the potentiometer made by Elliott Bros. 150. They are all made

* For a complete description the reader is referred to "The Potentiometer and its Adjuncts," by W. Clark Fisher ("The Electrician" Series).

equal to each other to within a very great accuracy. One of these sections (0—1) is laid straight (called the slide wire), and a movable key or contact can make contact at any point from 0 to 1. The other sections are made into coils, and another key in the form of a switch makes contact at any of the terminal points 1, 2, 3, 4, &c.

The slide wire has a scale which divides it up into 100 equal portions (10 in the Elliott instrument), which are equal as to resistance. By estimation each $\frac{1}{100}$th of the slide wire can be divided into tenths.

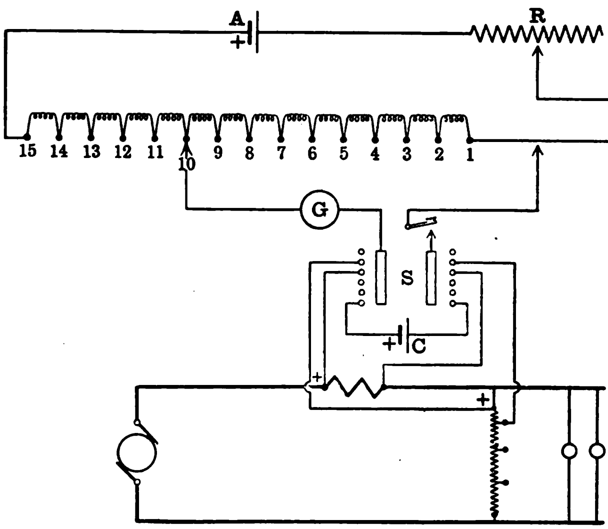


FIG. 167.—POTENTIOMETER CONNECTIONS.

An accumulator A, controlled by a rheostat R, supplies a constant potential of 1·5 volts to the extreme ends of the 15 sections; thus the voltage across each section is 0·1 volt, and across each $\frac{1}{100}$ of the slide wire 0·001 volt. A d'Arsonval galvanometer G, with a key, is connected through the six-way double pole switch S, first to a Clark cell for "standardisation" of the instrument, and then to the terminals of a high or low resistance for measuring current or pressure as shown. Any E.M.F. up to 1·5 volts can be measured direct, but higher potentials are connected to a standard high resistance, and a

known fraction of this high resistance is connected to the potentiometer. This resistance is termed a "volt box." Current measurements are made by having suitable standard resistances of known values, such as 1·0 ohm for 1·5 amperes, giving 1·5 volts drop at full load, 0·1 ohm for 15 amperes, 0·01 ohm for 150 amperes, &c. Such resistances enable the whole range of the potentiometer wire to be taken advantage of in the measurement of current; thus 1·5 amps., 15 amps., &c., are capable of being read to the fifth figure with ease.

With such an instrument care and cleanliness are necessary, as a dirty slide wire may lead to erroneous readings. The Author has had a Crompton instrument in use for some years in which the slide wire is enclosed in the case, and contact is made by a slider worked by an endless flexible steel band. This has given great satisfaction, and for commercial testing it certainly seems advisable to have the slide wire enclosed. Such a set, comprising potentiometer, standard cells, battery, galvanometer with lamp and scale, volt box, and standard low resistances is somewhat expensive. The low resistance shunts should receive careful handling, and when not in use are preferably kept locked up out of harm's way in order that they may not be damaged.

It is, therefore, worth while to provide a suitable stand in which the whole set may be set up and the standard resistances stored. Such a stand is seen in Fig. 168, which is built somewhat after the style of a pedestal desk. It is entirely of polished teak. The table rests on two pedestal cupboards, which contain the low resistances when not in use. Upon the table are placed all the other apparatus, consisting of the potentiometer itself, volt box, secondary cell, standard cells, galvanometer, with lamp and scale, all connected up and ready for use when required.

The table has a roller top, which shuts up all the apparatus, and keeps everything clean. In this way the instrument is always ready for use at a moment's notice, but at the same time is thoroughly protected when not required.

A shelf over the roller top is very handy for placing rheostats for regulating or for standing instruments on when calibrating. It also prevents anything being stood on the roller top.

Permanent leads of No. 20 wire can be run from a terminal board near the potentiometer to the various test tables and other points, and ended in pairs of terminals mounted on ebonite. From the main terminal board connections to the potentiometer or volt box are quickly made by means of 70/40 twin flexible leads. These flexibles should be braided, one black and the other red, in order that the positive and negative are easily traced.

If the ends of these flexible leads are soldered into hook connectors their life is considerably increased.

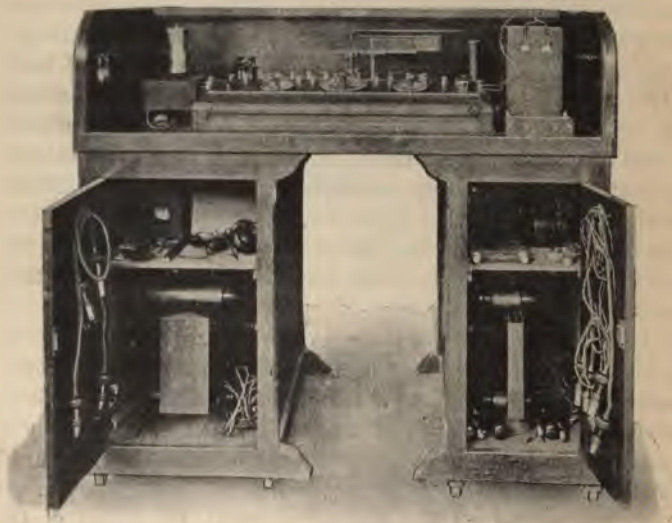


FIG. 168.—CROMPTON POTENTIOMETER SET, MOUNTED ON ROLLER TOP PEDESTAL TABLE.

Standard of Time.—Having standard instruments for the measurement of watts, amperes, volts and ohms, the meter test room still requires a further and most important standard instrument—that is, standard of time. Chronographs are most convenient instruments for timing the revolutions of some quick-moving portion of a motor meter, but it is very important that they should be frequently tested themselves and for the *same period of time that they are to be used for* in testing. These

time indicators develop starting errors and may change their speed, so that, if not checked, errors due to them might be ascribed to the meters under test. A chronometer is the most compact standard. Fixed in some convenient position, on a wall (away from mains carrying heavy currents) about 3 ft. 6 in. from the ground, it can be used with comfort for checking chronographs. For long time tests such an instrument is most useful, as also for rating clocks used in time switches or two-rate meters.

Beside the standard instruments others will be required. An ammeter and voltmeter of the capacity of each watt balance should be permanently fixed in the circuit. These should be suitable for alternating as well as continuous current where both are likely to be used; in fact, it is evident that all apparatus should be capable of working on either current in order that the whole equipment may be used, if necessary, to turn out work for one or the other system of supply.

For testing *in situ* portable instruments are, of course, required. Some very neat testing sets have been put on the market of recent years by several makers. For testing watt-hour meters of the motor type a wattmeter is to be preferred, as only one reading has to be taken. Good wattmeters of the portable type can be obtained suitable for both supplies. Where, however, testing is to be done on continuous-current circuits, permanent magnet instruments are to be preferred, as being dead-beat and unaffected by stray fields. They should always be provided with mirrors under the needle, as very true readings are required to prevent the errors in the test being greater than the meter errors. A portable low-reading ammeter (reading to 0·1) should be provided for measuring meter-shunt currents, and a portable voltmeter (reading to 1 volt) for the measurement of the drop in the main coils.

For the measurement of insulation resistance to case an ohmmeter will be found most convenient. A couple of ordinary detector galvanometers, with their batteries, are most useful for the testing and detection of faults in meters. These are more convenient if the batteries are enclosed in the same case as the instrument.

Frequency Measuring.—In alternating-current testing a frequency teller will be required. Should the testing department

be at the station, the alternators will be accessible and the frequency ascertained by taking the speed of the machines running. This would, however, take too much time, and an instrument should be close at hand by which the frequency can be easily read.

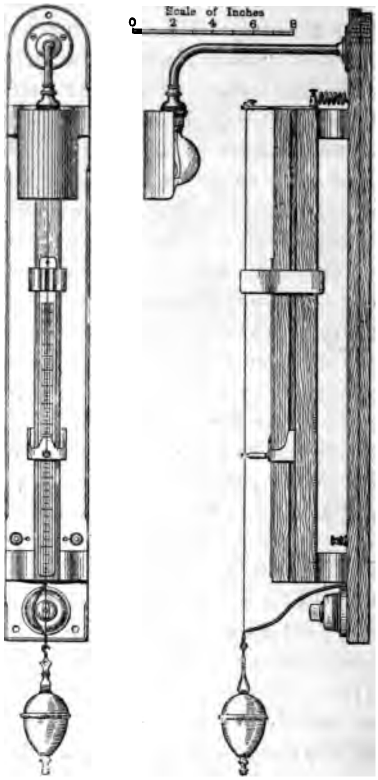


FIG. 169 —FREQUENCY METER.

A convenient form of frequency teller is that due to Mr. Albert Campbell, B.A.,* in which a thin iron strip is slid in or out of a clamp over the face of an electromagnet around which the current—the frequency of which is required—passes. The iron strip vibrates when its length from the clamp is such that

* *The Electrician*, Vol. XXXVII., p. 437.

its natural period of vibration is double that of the frequency of the current, when it emits a note. A rack and pinion to which the needle is attached are worked from the non-vibrating end of the strip, the needle indicating on the scale different points according to the length of strip free to vibrate. The scale can thus be calibrated in periods per second, the reading being obtained by sliding the strip until the note is audible.

Another method of measuring the frequency is by altering the length of a weighted wire carrying an alternating current and passing through the field of a permanent magnet. At a definite length the wire will vibrate. Fig. 169 illustrates an instrument made on these lines. The index slides up and down the beam in the front of which is the scale. To this sliding index is attached a rod, on the end of which is a jewel with a rounded hole through which the phosphor bronze wire passes, a weight being hung on the end of the wire. The weight is increased or diminished so as to get a suitable range, after which it is unaltered.

To use the instrument, the slider is slowly lowered until the wire vibrates to a definite amount. It is found that there is a definite point for each frequency where the wave appears to have a third wire, and this is the point taken. The instrument is calibrated by finding this point on known frequencies by slowly moving the slider down.

The length of wire free to vibrate, multiplied by the frequency, equals a constant; thus, by taking three or four readings on different frequencies the constant is determined for the given wire and weight and the scale then made.

Apparatus for Measuring Torque.—In order to measure the torque of meters it is necessary to have some sort of apparatus possessing small friction by which the pull can be measured.

In Fig. 170 such an appliance is shown. A vertical brass rod fixed to a lead base carries two brackets, the height of which can be adjusted. The top one supports a light wheel having a V-shaped rim and a steel spindle running in jewelled bearings. One end of a fine silk thread is attached to the main spindle of the meter, and the other end carries an aluminium scalepan, which weighs 1 gramme. The lower bracket acts as a rest for this scalepan. A box of weights and

a good micrometer—the latter for obtaining the diameter of the spindle—complete the set. When the silk is wound round the spindle, to obtain the effective radius at which the weight acts the spindle should be calipered itself and also over the silk, and half the mean diameter taken. In the case of meters having light main moving parts it is necessary to provide a duplicate set and place it so that its thread pulls in the opposite direction: then, if half the weight be put in each scalepan, a uniform moment is produced, and the meter main spindle is not pulled off its jewel bearing.

In using the apparatus, if 1 gramme, (the weight of the scalepan) is too heavy, a gramme weight can be attached to a very fine silk thread passing over the wheel to counterbalance the scalepan. For this purpose the silk used for galvanometer suspensions is the best. With meters having a high torque it is sometimes convenient to attach the silk to the rim of the brake disc, as by increasing the distance at which the weight acts the weight is reduced, as it acts at a greater leverage, and the tendancy to displace the moving part of the meter is thereby reduced.

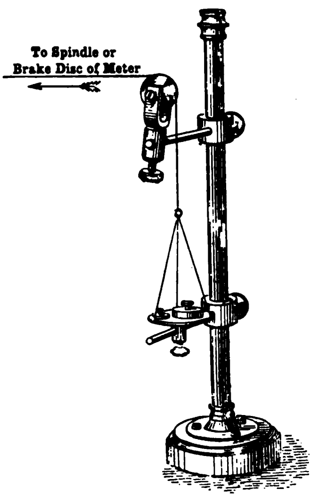


FIG. 170.—TORQUE MEASURING APPARATUS.

Although it is very satisfactory to see the actual weight being held up by the meter, measurements of torque with such an apparatus cannot be made quickly, and usually time is a consideration where much work has to be turned out. For the quick measurement of meter torques, therefore, a spring balance is perhaps the most convenient instrument to use, and very good results can be obtained in this manner very quickly.

An instrument of this description is illustrated in Fig. 171. It is easily made, and, by means of the previously-described apparatus, its calibration becomes a simple operation. Upon a piece of aluminium, A, about 0·2 cm. thick a small spindle, B,

is bolted, having lock nuts underneath. To the upper end of this spindle one end of a piece of watch mainspring, C, is fixed (either by soldering it in a saw cut or otherwise), and to the other end of the spring a straight piece of aluminium wire D is attached. This can be done by slightly flattening the wire, lashing it to the end of the spring with silk, and finally, shellacing the joint. The straight wire is allowed to project beyond the edge of the plate by about 1·4 cm., and at, say, 0·7 cm. from the end it is marked by a line to indicate the point to be used both in calibrating and when measurements are taken.

A small spirit level, E, is screwed to the plate as an indicator to show that the plate is at the same level when being used as

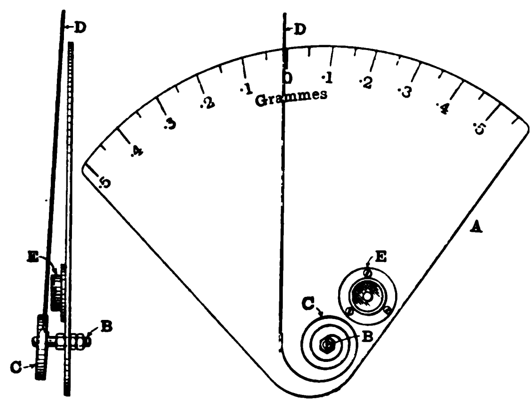


FIG. 171.—SPRING-BALANCE FOR MEASURING METER TORQUES.

when being calibrated. The level is necessary in order to avoid any error being introduced by the weight of the pointer, which would cause a deflection. The instrument is intended to be used with the plate horizontal, and the needle is set to a zero line by turning the spindle B. To calibrate this balance a loop is made at each end of a short length of very fine silk thread; one loop is passed over the end of D to the marked point, and different weights are hung on the other loop, the thread passing over the pulley of the apparatus previously described, which is adjusted for height. It is convenient to lay the balance on a box for this operation. The pointer being deflected, the plate

is turned in the opposite direction until the pointer is brought back to a position at right angles to the silk for each weight, and in this manner the points are easily marked on the plate on either side of the zero.

In using the instrument a small spring clip, made out of, say, No. 24 phosphor bronze wire, is slid on to the brake disc of the meter. The end of this clip is bent to stand vertical so as to meet D (at the marked point) at right angles. The plate is turned as in calibrating to bring the pointer D at right angles to the deflecting force. In the instrument illustrated the length of the pointer is 14·5 cm., and a deflection of approximately 2 cm. per decigramme is obtained. It is convenient to have two or three spring balances similar to the above, having varying ranges to suit various types of meter having different torques, or, by making clips which project beyond the periphery of the brake disc, the same instrument may be used. Where such clips are employed, care must be taken to ascertain that the disc has no tendency to rotate due to want of level and the weight of the clip. Owing to the use of magnets in so many meters, it is very important that the use of steel wire, either for the clip or for the pointer D, be avoided. Where the torque of a number of similar meters having discs of equal diameter is to be taken, it is convenient to make a clip, the end of which stands out from the axis of turning by preferably 10 cm., and to design the balance to give a good deflection when used with this clip. The torque is then ascertained without calculation, as the instrument can be calibrated in gramme-centimetres.

Although not an "instrument" in the sense the above apparatus have been described, the slide rule will be found extremely useful in the test room, either for checking calculations, or, if sufficiently accurate, for the working out of results. Slide rules having now become in almost general use, a description will hardly be necessary. With a Fuller slide rule results can quickly be arrived at after a little practice quite as accurately as ordinary tests can be made.

Resistances.—When the testing is done on a supply at 100 or 50 volts, it is necessary to provide resistance frames to dissipate the energy, and for alternating-current work these must be practically inductionless. They must also be capable of

regulation in small steps in order that varying strengths of current may be obtained. Banks of 100 or 200 c.p. incandescent lamps, with 32, 16 and 8 c.p. lamps, answer the purpose, but in order to avoid the glare, it would be almost necessary to keep them out of the test rooms. With water resistances, unless they are made very large in order to be worked at a low-current density, it is difficult to obtain a steady current owing to the great

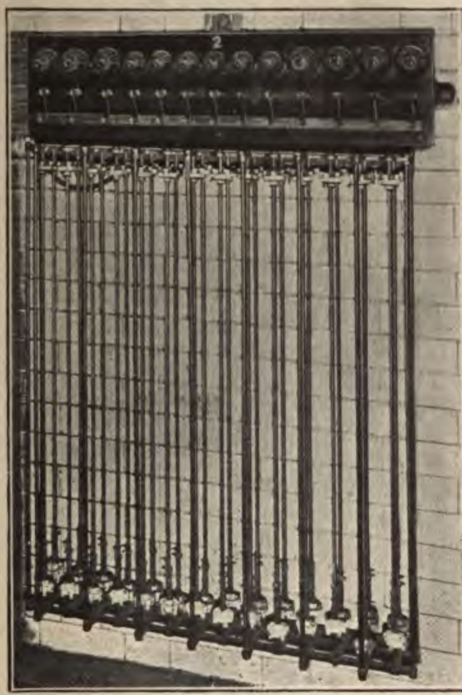


FIG. 172.—FLEMING INDUCTIONLESS RESISTANCE FRAME.

alteration of the resistance with temperature. The most suitable form of resistance for meter testing is the Fleming non-inductive "cage." A resistance frame built up of unit "cages" is shown in Fig. 172. The frame is of light cast iron at top and bottom, the two castings being fixed by rods at intervals. Above is a polished slate upon which switches and two 'bus bars with fuse terminals are placed.

The frame illustrated is capable of carrying $79\frac{1}{2}$ amperes at 100 volts, and the current can be altered from half an ampere up to the maximum by half-ampere steps, there being seven 10 ampere, one 5 ampere, four 1 ampere, and one $\frac{1}{2}$ ampere switches.

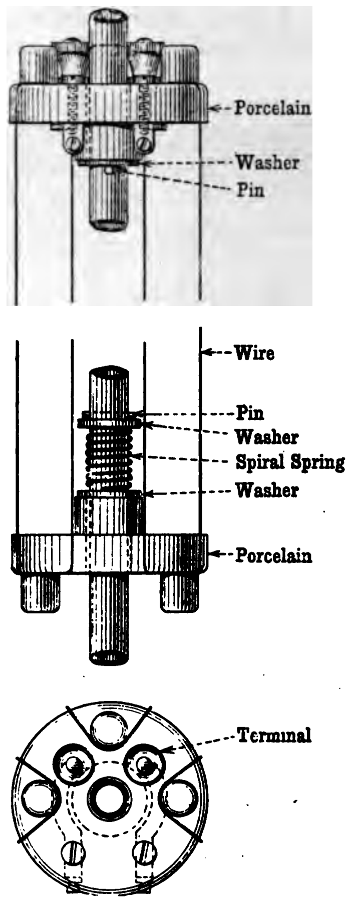


FIG. 173.—FLEMING RESISTANCE UNIT CAGE.

The "cages," or units, are connected up in parallel, each through a switch and fuse between two 'bus bars (one of which is at the back). Each unit is built up as follows:—On a hollow

brass rod, 3 ft. 6 in. long, are slid two circular porcelain discs, 1⅞ in. in diameter. These discs have circular projections, also of porcelain, on their upper surfaces (*see* Fig. 173), and the top one is provided with two terminals for receiving the ends of a platinoid wire.

One disc is fixed near the top of the brass rod with the projections upwards, the other, with its projections underneath, is kept near the bottom of the rod by means of a spiral spring, which takes the rod inside it, and tends to force the lower disc away from the upper one. One end of a bare platinoid wire is connected to one of the terminals of the top plate; it then passes round one of the projections on the bottom plate back to the top plate round a projection, and so on until the end is fixed to the other terminal. It will be seen how well such a cage is ventilated, consequently thin wires may be used and run at a high current density.

Each cage is held in the frame by a screw in the top and bottom castings, which passes through and enters the hollow brass rod. Leads are taken from the two terminals on the top plate to the switch and fuse terminal.

Should a wire burn out (which is a very rare occurrence) it is replaced quite easily, if the cage be removed from the frame. Such a resistance is practically non-inductive, and most useful for alternate-current testing.

The 10 ampere units are made up of three cages in parallel, each wound with a single No. 28 platinoid wire carrying 3·33 amperes; the 5 ampere unit contains two cages in series, each wound with No. 21; the 1 ampere and ½ ampere units each have one cage wound with a No. 36 and a No. 40 respectively.

Such a frame should be provided for each table, of the same capacity as the Kelvin balance. If in conjunction with the frame a 100 volt 16 c.p., a 100 volt 8 c.p., and a 200 volt 16 c.p. lamp* are wired up, the steps are reduced from ½ ampere to 0·15 ampere, and the lamps prove useful for testing the starting currents of meters. For the purpose of finally regulating the current and keeping it steady during testing rheostats will be necessary.

* A 200 volt 16 c.p. lamp will take about 0·15 ampere on a 100 volt circuit.

A very good one for the purpose is the carbon-plate rheostat, illustrated in Fig. 174, which can be obtained in various sizes. The one illustrated is capable of carrying 50 amperes, and has a range of about 0·03 to 1·5 ohms. It is composed of 40 pieces of battery carbon $3\frac{1}{2}$ in. square by $\frac{5}{16}$ in. thick, the surfaces being roughened. The regulation is obtained by altering the contact resistance between these 40 plates by tightening or loosening a screw which clamps them together. It has been found convenient, where these rheostats are used on the double test tables advocated, to have a hand wheel at each end, as in Fig. 174. If the rheostat is placed across the table somewhere about the centre it can then be worked from either side without having to be turned round each time. The carbon blocks are insulated from the frame by slate rods running along the

FIG. 174.—PAUL'S CARBON RHEOSTAT, FITTED WITH TWO HAND WHEELS.

length, and at the ends by means of a fibre strip fixed on the terminal plates between them and the plates upon which the ends of the adjusting screws press. The range of the apparatus can be altered by having other terminal plates not provided with the fibre insulation, which can be slipped in between any two carbon blocks. If one of these be inserted between the middle two plates of the set, and one pole connected to it, the two halves can be used in parallel if the other pole be joined to the two end terminal plates, thus doubling the ampere capacity.

Another form of rheostat most usefulfor meter testing is the Wirt rheostat. This is a wire rheostat which is practically non-inductive, owing to the manner in which it is made.

A high-resistance insulated wire is wound in a coil on a paper cylinder. This cylinder with the wire on it is then squashed flat and wrapped round a brass drum, being kept in position by cord bound tightly round it. The wire, therefore, lays on the drum parallel to its axis, the inside layer separated from the outside one by the flattened paper cylinder.

A sort of commutator is made by turning or filing the insulation for about ½ in. all round the outside layer, and a fixed brush makes contact at any point as the drum is turned. One end of the wire is connected to a ring driven over the binding cord, on which another fixed brush makes contact. By turning the drum the whole wire is put into circuit or gradually cut out, the steps being very small. Fig. 175 represents two such rheostats.

FIG. 175.—PAUL'S WIRT RHEOSTATS.

The one on the left has a resistance of 25 ohms. Having about 270 contacts, the resistance per contact is about 0·0925 ohm. It will stand a current of about 2 amperes without getting overheated, and is found very useful for regulating the main current during low load tests.

The small one on the right (Fig. 175) is used for regulating the pressure when testing watt-hour or watt meters. It has a total resistance of 50 ohms, and the number of contacts being 330, the resistance per contact is 0·151 ohm.

Another rheostat, which is more adapted to calibrating voltmeters, is shown in Fig. 176, and is one which is easily made.

It is a water rheostat, and consists of a glass jar, 11 in. high by 3 in. in diameter, which stands on a block of teak cleated to the upright board.

Two discs of lead form the plates, the bottom one being soldered to a brass rod which runs up inside the vessel, being covered by a piece of rubber tubing and connected to one terminal through a fuse fixed on the back of the upright board.

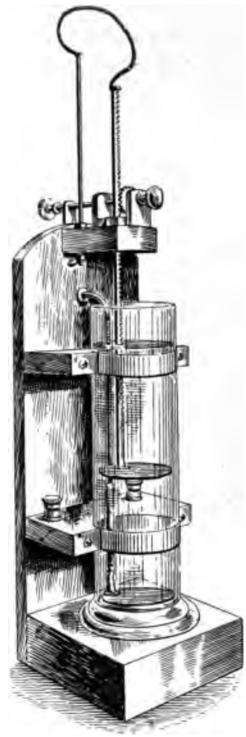


FIG. 176.—WATER RHEOSTAT.

To the centre of the other plate is soldered a small brass rack, which engages with a pinion fixed to the bracket over the jar. The pinion spindle has a milled wheel, preferably of ebonite, to insulate it, and the upper plate is thereby raised or lowered any desired amount. Such a rheostat has a very high resistance with the plates far apart. The plates are prevented from touching each other by a pin inserted in the rack, which forms

a stop. The motion should be made fairly stiff to prevent the rack running down, and, if necessary, a spring may be used as a brake, pressing against the pinion spindle. Should the resistance be too high, a drop or two of acid is added. Electrostatic voltmeters can also be compared throughout their range by using the rheostat and a lamp as a load across the terminals of the voltmeters.

For the regulation of large currents up to 500 or 800 amperes, such as would be used for testing station meters, the Author has designed and found useful the adjustable resistance shown in Fig. 177. It consists of six sets of six strips in parallel of german-silver, soldered at each end into brass blocks, which are mounted on slate strips, these latter being screwed to two iron bars at each end, which also serve for fixing the apparatus.

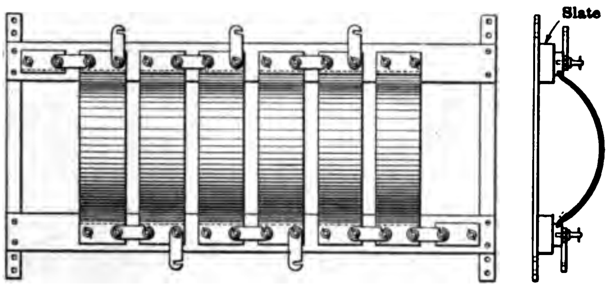


FIG. 177.—HEAVY CURRENT RHEOSTAT.

Each brass block has two thumbscrews for clamping a connecting piece which is hooked at one end, so as to fall on to the thumbscrew of the next block. By this arrangement the resistance can be connected up all in series, or in any combination, to all in parallel, such as two in parallel, three in series; four in parallel, two in series; and so on. It is found that final regulation can be made by tightening or loosening slightly the thumbscrews.

When the strips are all in series such a resistance will carry about 300 amperes without getting overheated for about half to one hour. All six in parallel will take 1,500 amperes quite comfortably for a short time. The resistance of each unit is approximately 0·000925 ohm at 270°F. The approximate length

of each strip is 15¼ in., width 3 in., and thickness of each individual strip 0·018 in. It is used with one or two large secondary cells for continuous-current testing, or with a step-down transformer (10 to 1 ratio) from the 100 volt supply on alternating current, when it becomes more convenient to regulate by inserting resistance in the primary of the transformer.

Choking Coils.—In alternate-current work it will be necessary to test certain meters on inductive loads. Meters which are intended for arc lamp or motor circuits should certainly be tested on inductive loads, as they will be expected to register the energy taken by such loads when erected on consumers' premises. The easiest way to obtain inductive loads is by inserting in the circuit a choking coil in series with the non-inductive resistances already referred to. It therefore becomes necessary in alternating-current test rooms to provide such coils, their size depending on the size of meters tested and

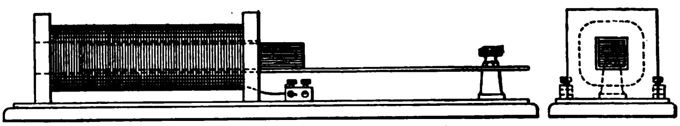


FIG. 178.—IMPEDANCE COIL WITH ADJUSTABLE CORE.

the amount of choke or lowness of power factor required. As a rule nothing lower than a power factor of 0·5 or 0·6 will be required, and these are fairly easily obtained by using ordinary straight coils with iron cores, capable of being pulled out of the coil, and provided with some means of fixing the core at definite points to prevent it being sucked back into the coil. Certain forms of arc lamp chokers are very useful for this work.

A choking coil for heavier currents than would be taken by a single arc lamp is shown in Fig. 178. This coil has 245 turns of two copper strips, each ¼ in. by $\frac{1}{16}$ in. The core is 13 in. long by 1¾ in. wide and 1½ in. deep. The coil is mounted on a board of about twice its length. Riveted to and underneath the core is a strip of brass just over double the length of the core and having a slit along it. This brass strip slides over the top of the pillar at the end of the board and is clamped at any position by means of the milled headed screw which passes through the slit. This makes a convenient coil for obtaining

power factors as low as about 0·1 with a current of 30 amperes on a 100-volt 60-period circuit. Two or three coils of similar design with various numbers of turns and sections of wire are very useful. Regulation can be effected either by sliding the choker core or by a carbon rheostat. A very convenient, though probably too expensive, arrangement for obtaining artificial power factor loads is to have two alternators and one continuous-current machine with their shafts joined by couplings, which allow of the altering of the relative positions of the alternator armatures. The angle of lag cannot, however, be assumed to be the angle of displacement of the armatures, as it would depend somewhat on the loads on the alternators. By regulating the speed of the continuous-current motor various periodicities can be obtained, and any power factor from 1 to 0 is also produced by arranging the lead of one alternating armature relatively to the other.

Transformers.—Step-up and step-down transformers are very useful for high-tension and alternating-current testing with heavy currents, and there should certainly be some at the disposal of the department. Large station meters would probably be selected which are suitable for power-factor loads, and consequently it is not important that they should be tested on a circuit of power factor = unity. It therefore becomes possible to test them, the main current being obtained from a step-down transformer, which avoids the necessity of providing a large energy-consuming resistance in addition to the advantage of the saving of the energy. Transformers for testing purposes are sometimes made with both primary and secondary windings split up into a number of coils, the ends of which are taken to terminal blocks, and so arranged that the coils can be connected up in different groupings, thus giving various ratios and current capacities.

Secondary Cells.—Where the continuous-current testing is done entirely on current taken from batteries, special cells for this work will be required. The end cells of a station battery might be used for such work, but this would lead to complications, as perhaps the testing cells would require charging when the main battery was fully charged. The number and size of

cells for supplying the main current depends on the number of meters tested in a batch and on their ampere capacity, but it

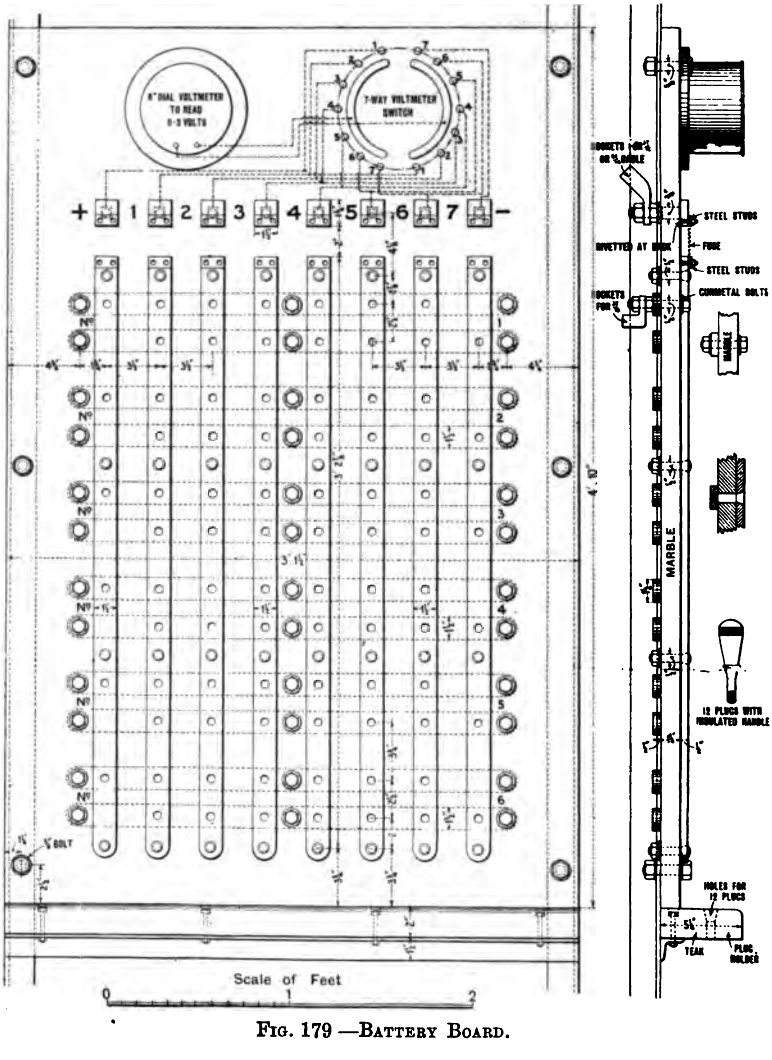


FIG. 179 —BATTERY BOARD.

is as well to have fairly large ones. In estimating the voltage required, it must be borne in mind that the leads, rheostat, and

standard instruments will cause a drop in addition to the meters. Assuming meters are tested six in series, and the individual drop on each meter of the smallest size in the type having the largest drop is 1 volt at full load, then it may be reckoned that the mains will cause a further drop of 0·1 volt and the standards and rheostat up to, say, 2 volts, so that a battery of four cells would be required to test the smallest meters six in series at full load. Taking the largest meters tested on the same circuit to be of 75 amperes capacity, having a drop at full load of 0·25 volt, the six meters would only require 1·5 volts, but the connections and leads, assuming the same to be used in both tests, would cause a further drop of 1·5 volts, so that for these the battery would require to be composed of two cells in series.

It is often advantageous to have more than six meters in series, especially if the only means of testing is by running to obtain readings, such as in the case of electrolytic meters. It is, therefore, a convenience to provide a circuit board for connecting up one or more cells to the various testing circuits according to the pressure required to send the current through the meters under test. A suitable board for this work is seen in plan and elevation in Fig. 179.* It is capable of connecting any number up to seven cells in series to six circuits. The ends of the circuits are taken to the horizontal bars, and one cell is connected between each vertical bar with a fuse in circuit. The board is 4 ft. 10 in. long by 3 ft. 2 in. wide, the bars being 1½ in. wide by ½ in. deep. By means of the seven-way selector switch above the bars the volts of any cell are readily seen by the voltmeter also mounted on the board.

For supplying the pressure circuits a small battery of cells of, say, 15 ampere-hour capacity would be required, the number of cells depending on the maximum voltage required. A motor generator or continuous-current transformer would be necessary for charging the "current" battery, the "pressure" one being charged off the station 'bus bars or battery.

Leads.—For connecting meters in series for testing, short leads are necessary between the meters. It is needless to say that these get an enormous amount of wear, and, unless some

* This board was shown diagrammatically in Fig. 151, p. 206.

special arrangement is adopted, annoyance is continually caused by these becoming too short for use. It will, therefore, be found most economical to provide leads with special ends which will be suitable for most types of meters, as the ends of flexible lead simply soldered soon require to be renewed. It is impossible to get ends suitable for all sizes as well as types, but two sets per table, with ends as in Fig 180, will be found to suit most meters which are fitted with screw terminals.

For meters provided with sockets it is a good plan to procure a number of spare sockets, and to make a set of leads by soldering "flex" of suitable section into them. This method avoids the trouble of soldering each time such a set of meters is tested.

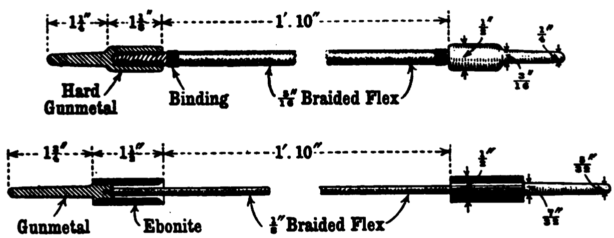


FIG. 180.—FLEXIBLE LEADS AND ENDS FOR CONNECTING METERS IN SERIES FOR TESTING.

Portable Lamps.—Each table should be provided with a portable lamp for the purpose of examining a meter closely to detect hairs or other causes of extra friction. Some meters also require to be tested with their covers on, and in these cases, in order to see the disc through the small window, a portable lamp is necessary. These should be shaded from the eyes, but on no account must the shade be made of tinned iron, as this, if held close to a meter, may divert some of the lines of the brake magnet, and cause the meter to run fast.

If straight filament candle lamps be used a very much smaller shade is necessary, and a more satisfactory portable lamp is the result.

For the purpose of making temporary connections a stock terminal connectors should be provided.

CHAPTER XI.

METER TESTING.

Meter testing comprises the ascertaining of the percentage errors, or verifying the constants of meters, and, if necessary, the adjustment of them so that they may be within certain limits of accuracy. The Board of Trade limit of accuracy is 2·5 per cent. on either side, and meters registering the consumption to within that amount are considered accurate. In addition to tests for accuracy, other tests are necessary, such as: tests of insulation resistance, tests of shunt resistance, tests of fall of potential in main coils, tests for alteration of constant after short-circuit, tests for starting currents, &c.

The simplest method of testing the accuracy of a meter is to run it on various constant loads and compare its reading with the number of Board of Trade units passed through. This method, however, apart from possessing the disadvantage of taking a long time, especially at low loads, may probably be more inaccurate than the meter itself, owing to the facts that the error of observation of the reading may be large unless a large reading is obtained, and that unless the current is kept constant the estimated Board of Trade units may not be correct.

A more accurate method is to take the speed of a fast-moving portion (in motor meters), such as the main spindle, with a definite number of watts or amperes passing, and to calculate the watts or amperes indicated by the meter after ascertaining the relation in speed of the moving part to the units dial. The error of the meter as a percentage of the *true watts* passed through it is then obtained by multiplying the difference between the true watts and the watts calculated from the speed of the meter's moving part by 100 and dividing the result by the true watts.

The result is given as positive if the meter over-registers, and negative if it under-registers. In using the error for arriving at the true consumption from the consumption as shown by the meter, in the case of a meter which has been out on circuit, it is wrong simply to deduct or add n per cent. from or to the registered consumption. The true consumption is arrived at as follows :—

If A = the consumption by meter,
x = true consumption,
p = percentage error (as a percentage of the true watts).

$$\text{Then } A = x + \frac{p}{100}, x,$$
$$= x\left(1 + \frac{p}{100}\right),$$
$$x = \frac{A}{\left(1 + \frac{p}{100}\right)}, \quad \textit{and not } A\left(1 - \frac{p}{100}\right).$$

The above difference becomes more important as the error of the meter becomes greater. Up to a 5 per cent. error, however, the difference is only $\frac{1}{4}$ per cent.

As an example, suppose a meter from the test is found to indicate 1,250 watts when only 1,000 are passing through it, the per cent. error as a percentage of the true watts is $100\frac{(1{,}250 - 1{,}000)}{1{,}000} = +25$ per cent. Now, suppose the units for the quarter, as registered by the meter, are 500, the true units to be charged for would be

$$\frac{500}{1 + \frac{25}{100}} = \frac{500}{1\cdot25} = 400.$$

If 25 per cent. were deducted from 500, $500 - 125 = 375$ units would be charged for.

If the error were expressed as n per cent. of the consumption in the above example, the meter would be said to over-register by $100\frac{(1{,}250 - 1{,}000)}{1{,}250} = 20$ per cent. of the consumption shown by the meter, and 20 per cent. of 500, or 100, would have to be allowed for.

On account of the uncertainty which occasionally arises as to whether the error has been given as a percentage of the true watts or of the watts recorded by the meter it is much more satisfactory for a "constant" to be given, this constant being the number by which the units registered must be multiplied to arrive at the true units.

Thus if K = this constant,

U_t = true B.T.W. passed,

and U_m = units indicated by difference in meter readings,

$$KU_m = U_t \text{ and } K = \frac{U_t}{U_m}.$$

Now, if H = hours during which W_t watts have been passing,

$$1{,}000\ H\ W_t = U_t,$$
$$\text{and } 1{,}000\ H\ W_m = U_m.$$

$$\text{Thus } K = \frac{1{,}000\ H\ W_t}{1{,}000\ H\ W_m} = \frac{W_t}{W_m},$$

where W_m are the watts passing as indicated by the test of the meter.

The test of a motor meter is quickly and accurately carried out by noting the time by a *tested* chronograph for a convenient number of revolutions of some quickly moving part (generally the brake disc). The number of revolutions counted is preferably a round number per ampere, and such that a time of about 100 seconds or more will be taken to perform the number of revolutions selected.

If T = the time in seconds in which R revolutions should be made if the meter were correct, and T_m = the time actually taken for R revolutions, the constant $K = \frac{T_m}{T}$. For $W_t T = BR$ and $W_t = \frac{BR}{T}$; also $W_m T_m = BR$, and $W_m = \frac{BR}{T_m}$,

$$\therefore \frac{W_t}{W_m} = \frac{T_m}{T} = K.$$

If a number of revolutions can be selected which, in addition to being a round number per ampere, also requires a time of 100 seconds, it will be seen that a hundredth of the time T_m taken is the constant K. Thus, if the main spindle of a 200 volt 10 ampere meter should make 40 revolutions (4 per

ampere or 1 per 50 watts) in 100 seconds at full load, the results of the test could be set down without any calculation thus :—

Watts.		No. of revolutions counted.		Time in Seconds.		"K."
2,000	....	40	....	98·6	....	0·986
1,000	....	20	....	99·2	....	0·992
500	....	10	....	99·8	....	0·998
100	....	2	....	108·6	....	1·086

A further advantage of varying the number of revolutions according to the load counted instead of the time for a constant number of revolutions is that the chronograph is run for approximately the same time in each test, and, therefore, if compared against a chronometer for the same period as used in the tests, all errors of the chronograph, such as starting errors (provided they are found not to be intermittent), do not affect the accuracy of the tests.

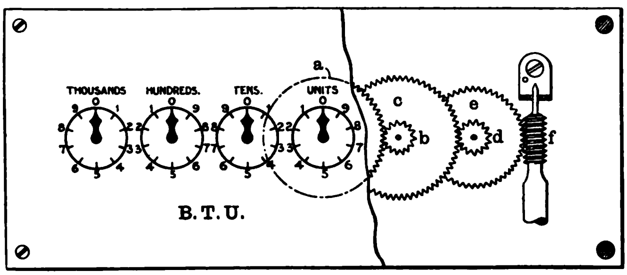


FIG. 181.—DIAL TRAIN OF MOTOR METER.

T, the time in which R revolutions should be made, is, of course, given by the formula $T = \frac{BR}{W_t}$, where B is the number of watt-seconds per revolution, and W_t the true watts supplied.

The number of watt-seconds per revolution "B" is found from the wheel ratios between the units dial and the part of the meter counted.

Fig. 181 represents a common type of wheel train with the front plate cut away to show the gearing from the units dial to the main spindle.

If a, b, c, d, e, f represent the numbers of teeth on the various wheels and pinions as shown, starting with the unit wheel (one revolution of which is equivalent to 10 units), then one revolution of units dial $= \frac{a}{b} \times \frac{c}{d} \times \frac{e}{f}$ revolutions of main spindle $= N$,

and as one revolution of units dial = 10 units = 36,000,000 watt seconds, N revolutions of main spindle = 36,000,000 watt seconds, and B = watt seconds per revolution = $\frac{36,000,000}{N}$.

In the case of ampere-hour meters of the motor type, B is obtained in the same way as for watt-hour meters. In fact, most ampere-hour meters have dials indicating Board of Trade units at the pressure for which they are intended. If the dials indicate ampere-hours, B becomes ampere-seconds per revolution. Meters which are calibrated in the first instance by altering the ratio between the units dial and the main spindle by the insertion in the wheel train of "change wheels" having

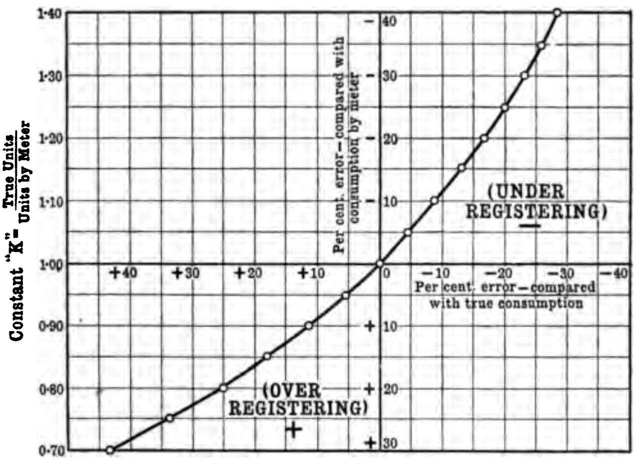


FIG. 182.

different numbers of teeth, naturally have several values for B in meters of the same size, and the true time is different in each case. It then becomes necessary either to count the teeth of each change wheel in each meter or to make a long time test at full load, at the same time making two or three counts of the quickly moving part, and thus to obtain B, which can then be used for the tests at lower loads.

In any case the change wheel ratio should be tested, as to test the meter without ascertaining that the wheel train is correct would be useless. Meters of this class should be provided with testing dials—*i.e.*, dials on which one complete

revolution is 1·0, 0·1, 0·01 Board of Trade units, in which case an accurate dial test can be made in a short time.

The curve, Fig. 182, shows the relation between per cent. (as a percentage of true consumption) and "K," the multiplier for units by meter. This curve is useful for ascertaining the constant of a wrong meter when the per cent. error is given.

Connections for Testing.—Connections for testing ampere-hour meters are simple enough. Any number may be connected in series, provided sufficient E.M.F. is available to obtain the required current in their circuit. Continuous current meters require to be connected up in the right direction; usually one terminal is marked positive, into which the positive lead should be inserted.

With watt-hour meters care is required in the connections. Their main coils are connected in series similarly to ampere-

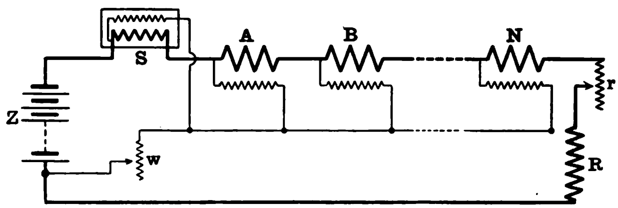


FIG. 183.—INCORRECT TESTING CONNECTIONS.

hour meters. If possible their shunt circuits are disconnected from the main coils, and are connected to a common lead having no appreciable drop, to which is also connected the end of the shunt-circuit of the standard wattmeter, or the voltmeter, and the test made on an artificial load.

If a number of watt-hour meters are connected in series it is absolutely necessary to proceed as above, as reference to Figs. 183 and 184 will show.

In these figures AB...N are the watt-hour meters, S the standard instrument, Z source of supply, R resistance frame, *r* carbon or other suitable rheostat, and *w* wirt rheostat for regulating the pressure. If the watt-hour meters are connected up for testing, as shown in Fig. 183, it will be seen that, owing to the shunt-circuits of the meters being left connected to the main, the standard instrument would register the current

taken by all the meter shunts in addition to the main current; B would register the shunt current of ...N; A those of B to N. It is also evident that the potential across the various shunts would differ, due to the fall of potential in all the main coils of meters to the left of the one considered; this varies according to the main current, and at full load would become important, causing each meter to run slower than the one to the

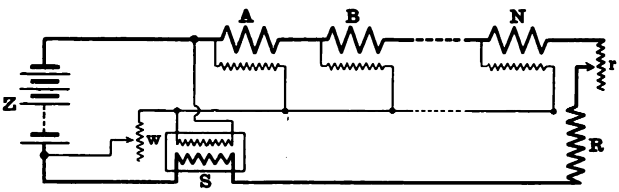


FIG. 184.—INCORRECT TESTING CONNECTIONS.

left of it. Inserting the standard instrument in the other main, as in Fig. 184, prevents the shunt watts of the meters being registered by it, but does not otherwise prevent inaccurate results being obtained.

If watt-hour meters are to be tested in batches in series it is essential to disconnect the potential circuit from the main, as in Figs. 185 and 186. In this manner all the shunts, including

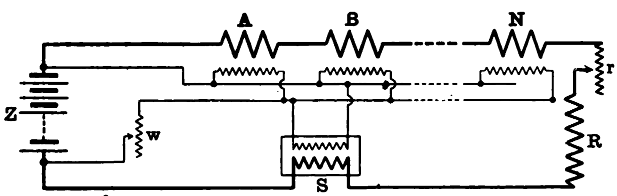


FIG. 185.—CORRECT TESTING CONNECTIONS.

that of the standard wattmeter, are fed from a common point, and none of the shunt currents are registered by the meters.

In Fig. 186 the shunts are fed from an independent source of supply, Z′, and as the main current is at a low voltage the power-absorbing resistance R may be dispensed with.

The two sources of supply may be joined as shown by the dotted line X Y in Fig. 186, in which case A might be tested

without disconnecting its shunt from the main; but, in order to test B in this way, it would be necessary to cut the main coils of A out of circuit, at the same time opening A's shunt, and so on for each meter. It is with this object that the standard instrument is placed in the opposite main to that in which the meters are connected, and this is the general arrangement shown in the diagrams of connections given in the Chapter on the "Arrangement of a Meter Testing Department."

A standard wattmeter may be replaced by a standard ampere balance and voltmeter on continuous current, or on alternating current of power factor = 1. It must be remembered, however, that the main coils are slightly inductive, and if the main current be taken from a low voltage transformer, without a non-inductive power-absorbing resistance in series, the power factor would not be unity. Even when the main coil circuit is supplied with current at 100 volts pressure,

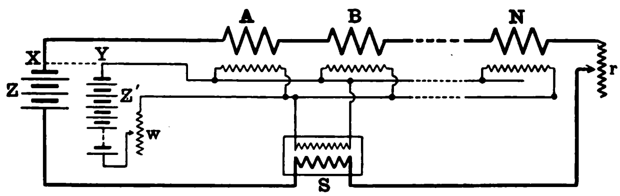


FIG. 186.—CORRECT TESTING CONNECTIONS. ARTIFICIAL LOAD.

an appreciable power factor is obtained with a few meters in series. On alternating current circuits, therefore, the testing of watt hour meters should only be carried out with a good wattmeter as the standard instrument.

In Figs. 185 and 186 the shunt circuits of the meters have been assumed to be normally connected to the "station" side of the main coils which is mostly the case in practice. Connected thus, the meter registers the watts lost in the main coils, but does not register those consumed in its own shunt circuit. If the shunt be connected to the "house" terminal of the meter the latter registers the shunt watts, but not those lost in the main coils, and if friction were balanced when the shunt circuit is disconnected from the main for testing, the meter might "creep," or register on no load when the shunt lead is replaced. Meters having, comparatively speaking, a great deal of friction, or meters of large size, could easily be

prevented from creeping when so connected. The connections for testing a batch of these could still be those of Figs. 185 and 186, and if great accuracy were required, the standard wattmeter should be set to what might be called a "false" reading to compensate for the change of connections for the test, so as to make the conditions similar to those when the meter is on circuit. An example will make this clearer.

Suppose a batch of 100 volt 10 ampere meters, one pole of the shunts of which in the normal way is connected to the house terminals, are being tested at a load of 1 ampere, and that the shunt watts of each are about the same, say, 3 watts; then, if the watt balance is set to 103 watts, and taken as 100 watts, the correct error of each meter is obtained, for on a low load the drop will be insignificant. At high loads the drop in the main coils must be considered, and in this example at full load, assuming each meter has a drop of 1 volt, the balance would be set at $1{,}003 - 10 = 993$ watts, and be taken as 1,000 watts.

If the end of the shunt cannot be disconnected from the main, owing perhaps to the meter being guaranteed for a period by the makers subject to their seals being unbroken, it then becomes necessary to connect up each meter separately as before. The watt-balance shunt will then be connected to the supply side of the meter, whilst the meter-shunt current will be taken from the "house" side. The correct error will be ascertained if the balance is set high by the amount equal to the watts lost in the main coils of the meter which will differ for each load. In the commoner case of the shunt being connected to the "station" terminal, if for any reason it cannot be disconnected for the test, then each meter should be tested separately, as at A Figs. 185 or 186, with no meters, B to N in circuit.

Three-wire Circuit Meters.—The usual difference between two and three-wire circuit meters is that the main coil is divided into two equal portions, one of which is connected into one outer and the other into the other outer of the three-wire circuit, the shunt or pressure circuit being connected to the two "station" terminals as in Fig. 187*. The neutral main is

* **Meters of different makes are connected up differently, that is to say, terminals 1 and 4 are not always the station terminals, but 1 and 3 may be, or any two.**

not, as a rule, connected to the meter. For the purpose of testing with balanced loads, the meters may conveniently be connected up as two-wire meters as in Fig. 188, the main coils being joined in series in the one main, so that they assist one another, and the shunt ends connected as in Figs. 185 and 186 to the special shunt circuit. After ascertaining that the errors

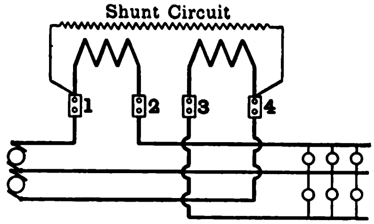


FIG. 187.—THREE-WIRE METER CONNECTIONS.

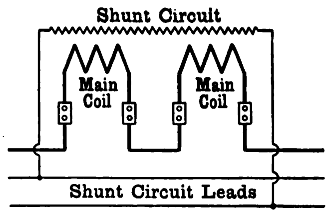


FIG. 188.—THREE-WIRE METER-TESTING CONNECTIONS.

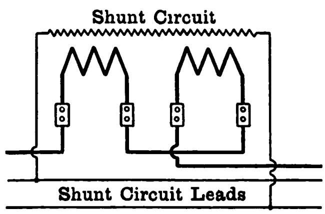


FIG. 189.—THREE-WIRE METER-TESTING CONNECTIONS. TEST FOR BALANCE OF THE COILS.

of the meters are within the allowable limits on balanced loads in the above manner, it is further necessary to check the effect which each half of the main circuit has on the speed. The limiting case of unbalanced load is load on one half and no load on the other. If, therefore, one main coil is cut out of circuit, the speed of the meter should be half of what it would

be at the same load with the two coils in circuit. If this is found to be the case the coils are balanced.

Another way of ascertaining this easily is to connect up the main coils so as to oppose one another (Fig. 189), and switch on full load or an overload (which will do no harm for a short time). If the coils are balanced, no motion of the main spindle will be noticed. If out of balance, the main spindle will rotate either backwards or forwards, depending on which of the two fields is the stronger. As the difference will probably be very small, the speed will be low. It is, therefore, advisable to use an overload, which makes the test more sensitive.

Polyphase Meters.—For the registration of the energy consumed in two or three-phase circuits single-phase meters may be employed, or meters specially constructed may be used.

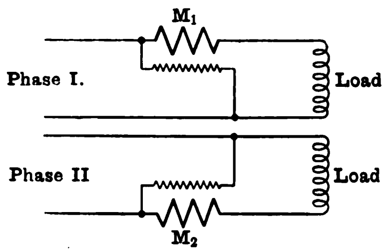


FIG. 190.—TWO-PHASE CONNECTIONS.

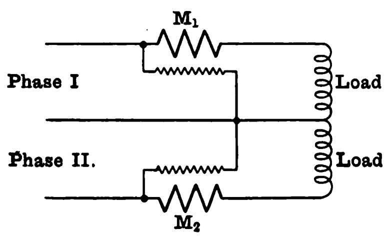


FIG. 191.—TWO-PHASE CONNECTIONS.

Two-phase circuits may be as in Fig. 190, in which case the two phases are separate and become two single-phase circuits, or as in Fig. 191 where the two phases have a common return. In either case two meters inserted as shown (M_1 M_2) would register the consumption, the total consumption being the sum of the two individual ones shown by each meter.

If the circuits are balanced, as in the case of two-phase motor loads, only one meter in one of the circuits would be necessary. This meter might be provided with a counting train to indicate the total energy, or if an ordinary meter be employed a multiplying constant of 2 would naturally have to be used.

Three-phase circuits are arranged in three different ways, as shown in Figs. 192, 193 and 194.

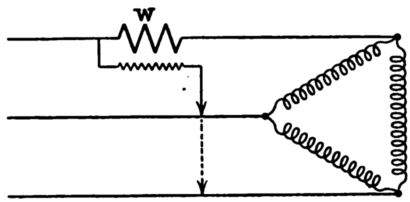


FIG. 192.—DELTA OR MESH CIRCUIT.

The measurement of the total power given to a delta or star system (Fig. 192) or (Fig. 193) can be made with one indicating wattmeter, provided the circuits are equally loaded. They may be inductive or non-inductive. The wattmeter main coil is inserted in one of the three leads, with one pole of its shunt connected to the same lead, and the other pole of its shunt is connected to the other two leads in succession The

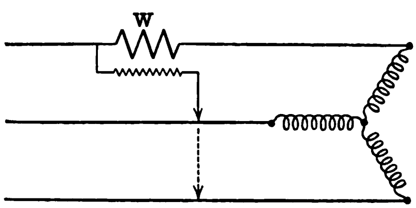


FIG. 193.—STAR OR Y CIRCUIT.

two readings W_1 and W_2 are taken, and the true power is: $W = KW_1 + KW_2$, where K is the multiplying constant of the wattmeter to reduce its readings to watts.

In the special case of the star or Y arrangement with a common return (Fig. 194) three wattmeters with their series coils inserted one in each main, as shown, with all their shunts connected to the common return, would be used, when the total watts would be $W = KW_1 + KW_2 + KW_3$, K being as before the

multiplying constants of the wattmeters. If each phase be equally loaded, one wattmeter would suffice, the true power being three times that obtained by the wattmeter.

If the circuits are unequally loaded in Figs. 192 and 193, two wattmeters would be required connected as in Fig. 195, when $W = KW_1 + KW_2$.

With an angle of lag of 60 deg. ($\cos \phi = 0 \cdot 5$) one wattmeter will read 0, the whole power being registered by the other

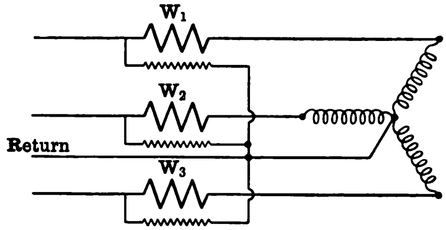


FIG. 194.—THREE-PHASE STAR CONNECTIONS WITH COMMON RETURN.

if $\cos \phi$ is less than $0 \cdot 5$, one wattmeter will read negative. The total watts in the case of an unequally-loaded system can be obtained with only one wattmeter by using a special switch, S_1 (Fig. 196), to throw over the series coils from one main to another. The shunt is then connected to the third main. Two

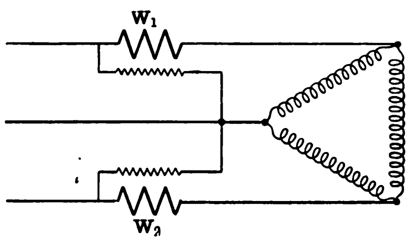


FIG. 195.—THREE-PHASE CONNECTIONS: UNEQUALLY LOADED CIRCUITS.

readings are taken: the current on each of the two mains, and the volts reversing. Key S_2 may be necessary in the shunt circuit, as the wattmeter may read negatively when thrown over. When a negative reading is obtained as above, the sign of one reading must be changed, the true power being the algebraic sum of the watts obtained by each reading.

From what has been said it is apparent that it is possible to meter the energy in a two or three-phase circuit by employing

two single-phase watt-hour meters connected as in Figs. 190, 191 or 195. This method, however, possesses disadvantages. Firstly, two meters would take up more room than one and would be more costly; secondly, two readings would have to

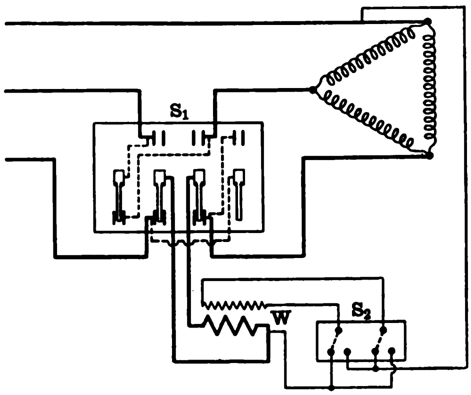


FIG. 196.—CONNECTIONS FOR MEASURING THE POWER IN AN UNBALANCED THREE-PHASE NETWORK BY MEANS OF ONE WATTMETER.

be taken (with the possibility of errors in reading), and their indications would have to be added algebraically, giving a further chance of mistakes being made. It is, therefore, preferable in every way to use a polyphase meter in which one

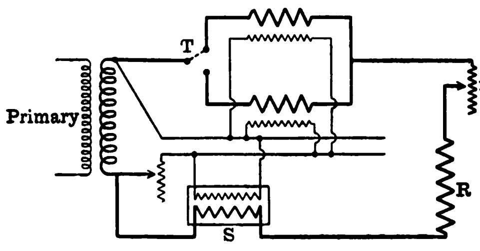


FIG. 197.—CONNECTIONS FOR TESTING TWO OR THREE-PHASE METER ON SINGLE-PHASE CIRCUIT.

set of dials gives the true consumption. Such meters are usually composed of two motors, either acting on a common disc or rotor, or on two discs or armatures carried on the same spindle; or, in the case of clock meters of the Aron type, which

have their pendulums and main coils arranged as previously described. Fig. 197 shows the connections which may be used for testing a polyphase meter on a single-phase two-wire circuit, such as those previously described. The meter is tested as two separate meters, but care must be taken that both shunt circuits are connected during *all the tests*. A throw-over switch T enables either of the main coils to be put into circuit and each is tested separately. The full-load speed on one main coil should be half the normal full-load speed of the meter.

Meters of large capacity for alternating-current circuits are often provided with series transformers, and, if for high pressures, with step-down transformers to reduce the voltage. By this means a standard small-size meter, with a special registering train which registers the kilowatt hours, taking into consideration the ratios of transformation, is usually employed. In such cases the meter itself may be tested, and the transformer ratios verified separately. It is preferable, however, to test the meter with its series transformer connected up as in practice. When step-down transformers form part of the meter set it is important that one of the tests on the transformer should be a "pressure test" from high-tension coil to low-tension coil, and to case or core, with a pressure of one and a half times the normal high-pressure voltage on which the set is to be used.

Testing Motor Meters.—A set of motor meters of the same size and make having been connected up in series on the test table and unclamped, the first thing to do is to examine all the counting trains to see that they are free, and that there is sufficient—but not too much—play between the worm and wormwheel. They should also be examined for constant—*i.e.*, that they have the correct train for their size. With meters having a uniform speed and constant, this becomes hardly more than a matter of inspection after a little practice, but a short dial run should also be made. The jewel should be quite smooth and possess a polished surface, which can be ascertained by feeling it with a sharp needle.

The brushes and commutators next require examining (in such meters as have them). Upon the state in which these are left depends to a very great extent the successful running

of this class of meter. The tension with which they press on the commutator should be just enough to prevent sparking with slight vibration. The correct tension is felt by lifting one brush off the commutator. The second brush should leave the commutator when the one lifted is between $\frac{1}{16}$ in. and $\frac{1}{8}$ in. from the commutator. Each brush should bear quite flat, and not on its edge: this is most important. The shunt current should not be left on while the brushes are being set.

It may save a lot of trouble if the compounding coil is tested to make sure that it is helping and not opposing. This is easily done by tapping the meter with the shunt current on, but no main current; the disc should then rotate slowly in the right direction. Meters having brake magnets should be carefully examined to see that no grit or particles of iron are between the poles and the brake disc, and that no hairs or stray threads are clinging to the armature.

Motor meters containing mercury are more difficult to examine, owing to the armature, or moving part, being enclosed and not visible. If friction is apparent by bad or non-starting, the first thing to examine, as in other motor meters, is the wheel train, especially where it gears with the main spindle. To examine the jewel it is necessary to empty the mercury. Sometimes bad starting may be due to contact of the main spindle with the clamping gear or to bubbles in the mercury, or perhaps an iron filing in the mercury chamber, in which case the mercury must be emptied out in the hope that it may bring the obstruction with it, fresh clean mercury being used to refill the chamber.

After having ascertained that the friction is not above the normal, and that the meter starts with the usual starting current, the full load may be switched on, and after running a short time the test at this load made. A test at a low load ($\frac{1}{10}$th or $\frac{1}{20}$th of full load) will then be sufficient for meters having a straight line law, but in those cases where the law is otherwise, tests at intermediate loads will be necessary. Induction motor meters are often faster at a middle load than at high or low load, and a test at half load is therefore advisable of meters of this class. They should also be tested on an inductive load of power factor of about 0·6 if at all likely to be used on inductive loads.

Some meters are affected by a short-circuit, the usual effect being a weakening of the brake magnets caused by the intense momentary field set up by the rush of current through the main coils. It is, therefore, advisable to cause a short-circuit through such meters by connecting them through a fuse of double the meter capacity to a supply at the correct pressure. It is not necessary to do this to every meter after it has been ascertained that no damage is caused. Many meters are provided with an iron plate between the coils and the magnets, which acts as a magnetic screen, and diverts the path of the field, causing it to pass through and above the screen instead of through the magnets. In some meters the magnets are placed so that their length is at right angles to the field of the coil, in which case they are little affected.

Where tests have to be made by taking readings, as in the case of the Aron and electrolytic meters, it is necessary to make the run long enough to produce a reading sufficiently large to prevent an error of more than 0·5 to 1 per cent. in the reading at the most. This means that a reading of at least 20 B.T.U. must be obtained on such meters as the Bastian or Wright electrolytic, or 2 on the last dial but one of meters possessing dial trains. A larger reading, however, is recommended.

The current and volts require to be kept constant by regulating during the test. Electrolytic meters, such as the Bastian or the Wright, which necessarily require a long run, may conveniently be tested by means of a good motor meter, such as an O.K., which can be standardised during the run.

In this way it is not necessary to regulate during the test, as the current variations ought to be felt both by the meters under test and the meter used as the auxiliary standard. Provision should be made for connecting up a number of such meters, as a quantity take very little longer to test than a few, the only difference being the extra time in taking the readings. It is desirable to test shunted meters at more than one load to ascertain if the curve is a straight line. If the cell circuit resistance is not properly compensated for temperature the errors will not be the same. The cell circuit may be tested for resistance at two temperatures, differing by about, say 15°C., when practically no difference should be found in the resistance if the compensation is correct. When the necessary tests

to ascertain the curves of the meters are completed, the shunt currents of watt-hour meters may be taken, as also the starting current, after which all current is switched off; the end of the shunt which had been disconnected from the main is replaced, and the meters are ready for insulation test to case.

The quickest way to ascertain the insulation resistance is with an ohmmeter and generator. The "line" lead is connected to one of the terminals of one of the meters, and the "earth" lead to the case. The shunt lead must be replaced before the insulation resistance is taken, otherwise the result would only be that of main, or of shunt circuit to case, according as to whether the "line" lead had been connected to a main or shunt terminal. The above tests are those which should be made on each meter intended to be sent out on circuit, and meters passing all these tests satisfactorily are ready for serial numbering and sealing.

Prepayment meters require further testing to prove the accuracy of the prepayment gear, which is usually an attachment to the ordinary meter. These tests include: (1) Checking the ratio of the additional wheels and pinions of the prepayment attachment, which is a similar operation to the ascertaining of the watt-hours per revolution. (2) Tests of the slot with actual coins. For this purpose it is desirable to collect a few new, medium, and very thin coins, as any and all of these will probably be used in practice. The slot should also be tried with other coins than those for which is the meter designed. For instance, a meter to take sixpenny pieces should not allow of farthings being inserted; one designed to take shillings must not have a slot capable of admitting halfpennies, and so on. (3) Tests of the cut-off gear and switch: Several trials should be made to ascertain that the cut-off gear acts without fail, and that the switch is not likely to stick in when it should come off. Equally important is it that it cannot, by shaking or otherwise, come off too soon.

The switch should be double break and quick break, its contacts being good. Switches in prepayment meters have up to the present not been particularly good, and the Author has had trouble with these, more especially in the contacts, the switch acting but not making good contact. This is a most important point in connection with prepayment meters, as nothing tends

to put this system of charging so much into disfavour as the fact that a consumer is left in the dark after having put the coin in.

It would be a long operation to test the meter for cut-off by running it even at full speed in the usual way. Several types of prepayment meters can, however, be run down by hand in a few seconds, and consequently many tests can be made in a short time. The method differs with each meter. When testing the cut-off in this way, on nearly reaching the point at which cut-off takes place the speed of running down should be reduced to the normal rate if possible, and care taken that the cut-off does not occur prematurely, due to shaking. It is not of great importance that the meter be within the $2\frac{1}{2}$ per cent. limit of accuracy when running to the point of cut-off at each test; probably this accuracy would not be obtainable. In most meters, if the cut-off takes place too soon on one occasion it will be too late on the next, thus the mean result by a number of trials is what is required; but there should not be a very large difference between trials, as the consumer would then notice the difference in the amount obtained per coin and would lose confidence in the meter, assuming he always ran to the last mite. As, however, owing to the inconvenience of being put in the dark, and to the fact that more than one coin can be inserted at a time, the probability is that prepayment meters are seldom allowed to cut-off in practice, consequently the error of a prepayment meter is not the one obtained by running to the point of cut-off, but the error when running ordinarily, like any other meter; this, however, in no way diminishes the importance of a positive action of the cut-off gear.

Demand indicators are very easy to test. A number are connected up in series with the standard instrument in circuit. They are all set to zero, and steady currents of different strengths are passed through them for the specified time (or perhaps a little longer at low loads). After each " run " a reading is taken. Those intended for motor loads should be tested with, say, 100 per cent. overload for a minute or two. If provided with two scales, which is usual, one being calibrated in amperes and the other in units to be consumed per quarter (or other period) before the reduced price is charged, the latter scale should in

each case be checked by calculation at a low, high, and intermediate point.

Sample meters—that is to say, meters of a new type not previously employed—should be further tested for torque, effect of temperature and drop.

Torque Tests.—The full-load torque of meters varies from about 30 gramme centimetres down to about 1 gramme centimetre, the torque of the majority being considerably under the higher figure mentioned.

It being essential that the torque necessary to overcome friction be a small fraction of the full-load torque, the former naturally becomes a very small force indeed.

Very little has hitherto been written on this subject, but Mr. S. Evershed, in an appendix to his Paper, "A Frictionless Motor Meter,"* gave a lot of information.

The forces tending to retard the motion of a motor meter are brake friction, mechanical friction and air friction. Brake friction is proportional to the speed, mechanical friction is practically independent of the speed, and air friction approximately proportional to the square of the speed. The latter becomes of little importance if the full-load speed is kept low and if the moving portion has no parts which will act as fans when rotating. If air friction is neglected and

F = torque necessary to overcome friction,
B = brake torque at speed = 1,
T_1 = torque at speed = S_1,
T_2 = torque at speed = S_2,

$$T_1 = F + BS_1,$$
$$T_2 = F + BS_2,$$

from which F and B are easily found.

$$B = \frac{T_2 - T_1}{S_2 - S_1} \text{ and } F = \frac{T_2S_1 - T_1S_2}{S_2 - S_1}.$$

If air friction is taken into account, since this may be taken proportional to the square of the speed,

$$T_1 = F + BS_1 + AS^2{}_1$$
$$T_2 = F + BS_2 + AS^2{}_2,$$

* *Journal*, I.E.E., Vol. XXIX., No. 146, July, 1900. *The Electrician*, Vol. XLV., p. 513.

where A is the coefficient of air friction. A third result must, therefore, be taken at another speed,

$$T_3 = F + BS_3 + AS^2_3.$$

From these three equations the values of F, B and A can be found :—

$$A = \frac{(T_3 - T_2)(S_2 - S_1) - (T_2 - T_1)(S_3 - S_2)}{(S_3 - S_2)(S_3 - S_1)(S_2 - S_1)},$$

$$B = \tfrac{1}{2}\left\{\frac{T_3 - T_2}{S_3 - S_2} + \frac{T_2 - T_1}{S_2 - S_1} - A(S_3 + 2S_2 + S_1)\right\},$$

$$F = \tfrac{1}{3}\{T_3 + T_2 + T_1 - B(S_3 + S_2 + S_1) - A(S^2_3 + S^2_2 + S^2_1)\}.$$

To obtain F it is necessary to considerably weaken the brake. This is not possible in some meters, but where the brake is a magnetic one, the magnet being used only for the brake, this can easily be done by moving it away so that the edge of the brake disc only just comes between the poles; or the magnet (or magnets) may be replaced for the test by a very weak one. Under these conditions some time should elapse after the current is switched on before taking a count of the revolutions, as the armature will be slow in attaining its constant speed. For this reason several counts should be made, and the first ones rejected if it is found that the speed is increasing. With the weakened brake very small currents will, of course, be required. If the brake be weakened in the ratio of $\frac{1}{20}$, about $\frac{1}{20}$th of the full-load current will produce full-load speed. Apparatus for measuring the torques T (in gramme centimetres) was illustrated and described in the previous chapter. The procedure is as follows: With a definite weight in the scale pan, increase the current by regulating until the weight is lifted off its support. When quite off the support, regulate until no motion is obtained, and note the watts or current. It is as well to regulate up and down to the point where the moving system of the meter just starts moving, first forwards and then backwards. In the case of meters having an uneven turning moment, measurements must be taken for several positions of the moving system, and the mean result taken. Here the current should be kept constant, and the weights altered to the correct amount.

The full-load torque is obtained quite easily, and, unless the friction torques are required, there is no need to reduce the brake power. If, however, the full-load torque is small, the torque may be measured at an overload, assuming, of course, that the torque is proportional to the load, which can be determined by taking the speeds at various loads and overloads. For the purpose of comparing the quality of two meters of fairly similar design, it can be seen that the resultant friction in each would not be very dissimilar when properly compensated; then the full-load torque is the important factor. Most meters in which the friction is comparatively large are compensated for friction. By this means, if carried to extremes, it is possible to make the friction torque a negative quantity—that is to say, the meter will run on no load. In a compensated meter, therefore, although the actual friction may be relatively large, the effect of this compensation makes it small (and consequently difficult to measure). The drawback to such compensation is that it is only correct so long as the friction remains constant. The measurement of the counter-frictional torque is a tedious operation, in which it is difficult to avoid large errors in the results obtained. This measurement is, however, from a practical point of view, unnecessary. The curve of a meter depends on the ratio of full-load torque to counter-frictional torque; but the curve of accuracy of a new meter is easily obtained by testing at various loads, and if found satisfactory it is a proof that the above ratio is sufficiently high.

From the supply undertaking's point of view—as also the consumer's—the *permanence of the accuracy* is the important point, and this depends on the driving torque to a large extent. The friction may increase with time, but the higher the driving torque the less the curve of accuracy is affected by a given increase of friction. The increase in the friction in no way depends on the initial friction, but on mechanical details, such as quality of jewel, accurate cutting of wheels in train, dust, &c.

The effect of friction is seen in the following two Tables. It is assumed that the two meters require the same torque to overcome friction when new, and that the friction increases with time in each case by the same amount:—

No 1 Meter.—Full-load Torque = 100.

Load.	Torque.	F_1.	% error slow.	F_2.	% error slow.
Full	100	1	1	2	2
Half	50	1	2	2	4
Quarter	25	1	4	2	8
One-tenth	10	1	10	2	20
One-twentieth ..	5	1	20	2	40

No. 2 Meter.—Full-load Torque = 200.

Load.	Torque.	F_1.	% error slow.	F_2.	% error slow.
Full	200	1	0·5	2	1·0
Half	100	1	1·0	2	2·0
Quarter	50	1	2·0	2	4·0
One-tenth	20	1	5·0	2	10·0
One-twentieth ..	10	1	10·0	2	20·0

F_1 torque required to overcome friction.
F_2 torque required to overcome friction when increased with wear.

From the above it is apparent that an increase in friction of 100 per cent. would cause an increase of 10 in the percentage error of No. 1 meter (low torque) at one-tenth of full load, and only an increase of 5 in the percentage error of No. 2 (high torque) at the same load.

Tests for Effect of Temperature.—Tests for the effect of temperature on the constant of a meter are made in exactly the same way as the ordinary tests. For rough tests the meter may be heated by a heavy current (full load, or more provided that it is not too high to damage the meter), a hole being drilled in the case for the insertion of a thermometer. To save energy this current is taken from one secondary cell and is kept on several hours. If there is room inside the case, another current may be used to heat a resistance placed so as not to touch the moving part. The current in the heating resistance should be switched off during each test, and switched on directly afterwards.

For more accurate results an oven, capable of taking the meter, with a glass door to enable the temperature to be read and also a count of the revolutions made, is required.

Mr. G. W. Donald Ricks, in a Paper read before the British Association at Toronto,* entitled "Some Tests on the Variation

* *Electrician*, Vol. XXXIX., pp. 573, 601.

of the Constants of Electricity Meters with Temperature and with Current," describes a tank or chamber in which the meters were fixed for test. This apparatus is composed of two copper tanks, one inside the other, the inner one being $2\frac{1}{2}$ in. smaller than the outer in all directions, and kept central by means of wooden distance-pieces with holes through them. The space between these two tanks is filled with water, which is kept at a constant temperature by passing steam into it at high temperature. To prevent the heat escaping, these tanks are placed in a wooden box, the intervening space between this box and the outer tank being filled with sawdust.

CHAPTER XII.

THE TESTING OF METERS IN SITU.

In a large electric light undertaking a number of accounts will be disputed each quarter, and to settle these it is necessary to make a test of the meters in situ. Apart from the tests made for the above reason, it will be found economical to test meters in situ at intervals in order to ascertain how they are working, A staff of men (the number depending on the number of meters installed) should, therefore, be organised for this work. Each tester should have a youth to carry the instrument, leads, &c., whose duty it becomes to watch the reading of the standard instrument during the test. The tester should be provided with a bag containing lamp socket wired and lamp (for testing the starting currents), and the necessary tools for connecting and disconnecting the instruments, cleaning commutators of such meters as have them, changing jewels where necessary, and sealing up meter terminal box after making the test.

The meter may preferably be loaded with the consumers' lamps, or a portable resistance composed of a bank of lamps may be used. Fig. 198 illustrates a portable lamp resistance suitable for this work. As will be seen, eight batten switch lampholders are fixed to a $\frac{1}{2}$ in. teak board 16 in. by $7\frac{1}{2}$ in., which forms a false bottom, another teak board being screwed underneath, leaving sufficient room for the wiring. Flexible leads, having suitable ends for inserting into the wattmeter and watt-hour meter terminals, are taken to the two single pole fuses, from which the lampholders are wired in parallel. The box illustrated, if fitted with four 32 c.p., two 16 c.p., one 8 c.p. and one 200 volt 16 c.p. lamps, will consume about 670 watts on 100 volt circuits. The 200 volt 16 c.p. lamp is useful for

testing the starting current. The above arrangement of lamps would serve for testing meters up to 10 amp. capacity, as it would not be necessary to test a meter of this size at a higher load. Larger lamps and more of them could be used, but a portable set should not be made too bulky. If possible it is better to use the consumers' lamps, as the average evening load can then be asked for, and the test made at this load. A second test can be made afterwards at a lower load.

The easiest and quickest way to make a test in situ of a motor meter is by counting the revolutions of the disc and comparing the watts by meter with the watts as indicated by the portable wattmeter, or the current by meter with the current by ammeter in the case of ampere-hour meters.

FIG. 198.—PORTABLE LAMP BOX FOR TESTING IN SITU.

For watt-hour meter-testing a wattmeter is more convenient than an ammeter and voltmeter, as only one reading is necessary, and it must be remembered that when testing in situ it is not so easy to keep the current steady. For this reason, apart from the question of carrying the apparatus, it is necessary to have the second man, who should watch the reading of the portable instrument during the counting of the revolutions by the tester. Good chronographs should be provided for this work, and these should be checked against the chronometer or standard clock night and morning. The

portable instruments should also be standardised frequently, as the constant carrying about and use is a severe strain on delicate instruments. The Author has had considerable trouble with shunted instruments for this work. It is unfortunate that instruments of this class are unsatisfactory for testing in situ, as a set of shunts for one instrument enables such good readings to be obtained at widely different loads. It has been found, however, in practice that in time the constant connecting up and disconnecting, together with the coiling up of the flexible leads provided with these shunted instruments, causes a few strands of the flexible lead to break. These broken ends may make contact intermittently, causing variable readings to be obtained. The resistance of the shunted circuit being small, very little alteration in the resistance of the leads makes considerable difference in the reading of the instrument. Owing to this defect, it is preferable to use instruments which carry the whole main current, whether they be ammeters or wattmeters.

When non-inductive wattmeters are used, two readings should be taken with the current in both coils reversed, in order to eliminate any effect due to stray fields. It is convenient, therefore, to include a portable switch in the outfit, which will enable the change-over to be made quickly and conveniently.

The dials of instruments used for this work should be fitted with mirrors under a very thin pointer, to avoid errors in reading due to parallax.

The errors of test must obviously be kept as low as possible, otherwise meters which are within the limits of accuracy might appear inaccurate, and vice versa.

By taking two or three counts of a suitable number of revolutions of the quickly-moving part, and obtaining the mean, errors of observation in counting will probably cancel out, but errors due to parallax do not cancel out, as they depend a great deal on the observer.

The results should be worked out immediately a test is made, before the load is altered, as it is then possible to repeat a result if it appears wide of what it should be. In so doing a lot of the doubt as to whether a mistake has been made in the test is removed. For this work a slide rule is almost an essential part of the outfit.

All calculations should be checked by an independent person, such as the clerk who attends to this work, before the constants obtained by the tester are made use of and an apparently inaccurate meter changed.

Each tester should be provided with a table of the testing constants (or watt seconds per revolution) of all the sizes and types he is likely to come across on his rounds. This simplifies his calculations considerably, his formula being $W_m = BR/T$, where W_m = watts by meter, B = watt seconds per revolution, R = revolutions counted, T=time in seconds for R revolutions. Or the constant K (which is the multiplier for the watts by meter to make the meter correct) is obtained at one operation: $K = W/W_m = WT/BR$, where W = the true watts as indicated by the portable instrument (using a correction if necessary). The same formula holds in the case of ampere-hour meters, but W is arrived at by multiplying the true amperes by the declared pressure.

If several types of meter are employed, and owing to the fact that nearly every maker gives a different formula and testing constant, unless some general rule is adopted for all makes, great complications arise. Those meters which are calibrated in the first instance by altering the wheel ratio of the train, and in consequence have variable values for "B" for meters of the same capacity, should have the value in each case stamped on the dial or in some position where it can be seen without breaking the seal, and where, at the same time, it is not likely to be rubbed off or painted out. In checking the results of tests of such meters reference should always be made to the value of the constant given in the test book, which should agree with that on the meter.

Meters other than motor meters cannot be tested in situ in the manner just described. The only way to obtain a test on these is by connecting another meter in series, and leaving it up for a week or more, until readings are obtained large enough to be compared accurately. This method of testing in situ is only to be recommended in the case of electrolytic meters, for it is much more costly, necessitating two visits, and means reserving a stock of meters. In the case of watt-hour meters provision has to be made for taking the shunts of the two meters to a common point.

Connections.—With ampere-hour meters the connections are simple. The portable ammeter is inserted preferably between one of the meter terminals and the lead which is taken out of this terminal. Watt-hour meters and the portable wattmeter

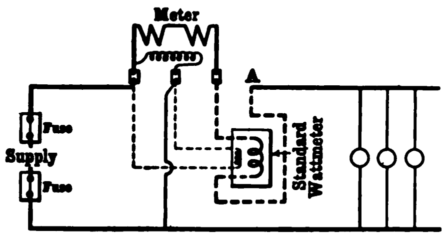


FIG. 199.—CORRECT CONNECTIONS FOR TEST OF A WATT-HOUR METER IN SITU, USING CONSUMER'S LAMPS AS LOAD. THE DOTTED LINES INDICATE THE TEMPORARY CONNECTIONS.

must be connected up as in Figs. 199 and 200; the shunt circuit of the wattmeter is isolated from the main coil, and the latter is inserted on the "house" side of the meter under test. The leads from the wattmeter shunt terminals are connected

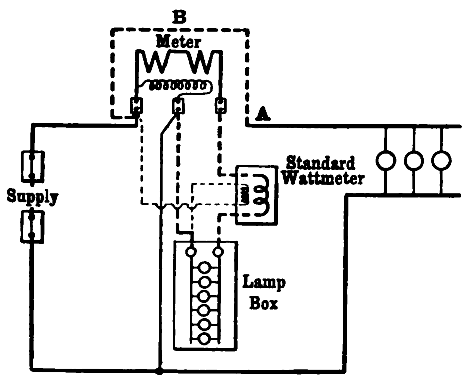


FIG. 200.—CORRECT CONNECTIONS FOR TEST OF A WATT-HOUR METER IN SITU USING PORTABLE LAMP BOX AS RESISTANCE, CONSUMER'S SUPPLY BEING UNINTERRUPTED. THE DOTTED LINES INDICATE THE TEMPORARY CONNECTIONS.

to the supply main terminal and shunt terminal of the meter respectively. If a lamp box is used, the connections would be as in Fig. 200. The house lead A is removed from the house terminal of the meter as before, and if connected to the station

terminal by a lead B, the test can be made without interrupting the supply. It will be noticed that with the connections shown the current passing through the portable lamps passes through the shunt tee. For large loads this would not be safe, but up to 10 amperes no harm can be done to this lead for the short time during which the current is kept on.

Testing in situ, if done properly, also becomes a check on the wiring of the house. It is very often difficult to trace wiring (especially additions), and it sometimes occurs that a lamp or lamps may be connected on the station side of the meter. The tester should, therefore, always be on the look out for such unmetered circuits, which are easily found out by leaving the end A out of the meter and trying to turn on suspected lamps, which, of course, would only glow if connected to the wrong side of the meter.

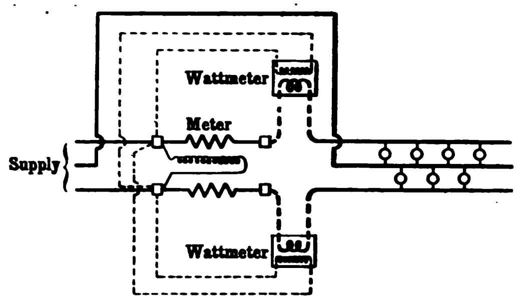


FIG. 201.—CONNECTIONS FOR TEST OF A THREE-WIRE WATT-HOUR METER IN SITU, USING TWO WATTMETERS (APPLYING A CONSTANT OF 0·5 TO OBTAIN THE TRUE POWER IF THEIR SHUNT CURRENTS ARE NORMAL).

Three-wire circuit meters are not easily tested in situ; it is therefore preferable to change them and test them in the test room. Unless a specially-designed wattmeter is obtained, having its main coil divided into two halves, well insulated from one another (to be capable of withstanding the pressure between the outers of the three-wire system without breakdown), it becomes necessary to use two wattmeters, as it is practically impossible to be sure that the load on each arm is the same.

The main coils of these instruments are inserted in the two outers on the "house" side of the meter, and their shunt circuits connected up to the station terminals of the meter and a

point on the neutral. It might be more convenient to connect both shunts of the wattmeters, including the necessary added resistances, in parallel across the two outers, in which case they would be under the same conditions as the meter—*i.e.*, the wattmeters would take no account of any slight difference in the pressure which might exist on the two arms, due to unequal loading. Neglecting this difference—which would be small—if the shunt currents of the wattmeters were normal, a

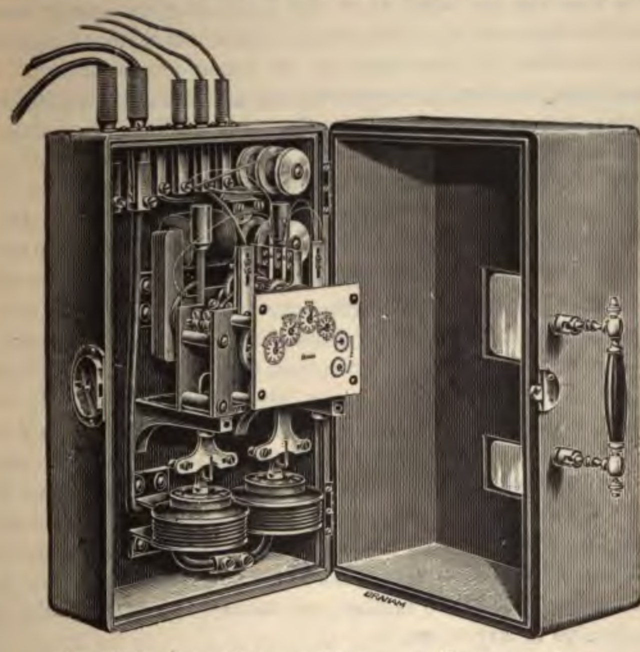


FIG. 202.—ARON PORTABLE METER FOR TESTING IN SITU.

constant of 0·5 would have to be used, as the instruments would indicate twice the actual watts passing. The connections for this test are seen in Fig. 201. Three-wire meters are usually of large capacity, and, apart from the difficulties of properly measuring the power by means of standard instruments when testing in situ, there arise others, such as the insertion into the circuit of these instruments where the mains are heavy and end in special sockets, and the practical impossibility

of keeping the load steady during the test, owing to the probable switching off of lamps. Portable lamp banks would be too cumbersome in large sizes.

In the case of meters provided with dials indicating tenths and hundredths of a B.T.U., tests in situ may be made by means of a standard meter, also having dials showing fractions of a unit. The standard meter would be connected temporarily in the circuit and both meters read. The connections in this case are the same as if the indicating wattmeter were used as shown in Fig. 199, so that the shunt watts of neither the standard nor the meter to be tested are registered. A load is switched on for a short time and the consumption by each meter ascertained. This method is perhaps more simple than that in which a stop watch and standard wattmeter are used, but where meters have no dial lower than the "units per division" one, such a test would take too long. The Aron Electricity Meter, Ltd., make a special type of meter for such work, which is illustrated in Fig. 202. This instrument is similar in principle to the ordinary clock meters of this make previously described, the chief difference being in the balancing of the pendulums and their spring control, which avoids the necessity of having the meter absolutely plumb. By an arrangement of plugs and sockets, which, in sizes up to 50 amperes, are, as shown in the figure, at the top of the meter, the instrument is made suitable for various voltages and for both alternating and continuous current circuits. This meter is made in sizes up to 400 amp. capacity. Were it not for the fact that comparatively few meters are provided with the fractional dials, this method of testing in situ would be preferable to any other.

CHAPTER XIII.

ERECTION OF METERS ON CONSUMERS' PREMISES.

METER-READING.

So much depends on the careful fixing of meters that the work should only be entrusted to competent and careful men. The choice of a site is of considerable importance, and needs some knowledge of the construction of the meter to be fixed, for the site which might be suitable for one type might be totally unsuitable for another, owing to vibration or space. The space which is required by a meter does not in all cases mean simply the amount of wall area upon which it can be fixed. Many types require head or side room, in order that the case may be removed without taking the meter down. In some instances more than double the actual area required for fixing must be left. The best height for the meter from the floor is about 5 ft. or 6 ft. At such a height it is conveniently read, and at the same time is not likely to be damaged. Meters should on no account be fixed on partitions or near any banging door, as the shock received by the jewel each time the door is closed is bound to wear it very rapidly. Lath and plaster walls should also be avoided where possible, especially with heavy meters, as trouble is very likely to be caused by the meter falling forward and so getting out of level.

The meter should not be fixed directly on to the wall, but on a "backing board" firmly screwed to the wall. Such a board, which has been found to answer its purpose very well, is seen in Fig. 203, p. 285. It is made of whitewood and varnished. These boards are about $\frac{7}{8}$ in. thick, and the battens at the back

2 in. wide. Porcelain bushes are provided through which the fixing screws pass. The board can either be fixed flat on the wall, or it can be kept clear of the wall if insulators are used behind as shown. From the enlarged section through the fixing hole it will be noticed that for the front porcelain bushes the board is countersunk in order to keep the face of the board clear of obstructions; the back insulator, however, stands out from the crosspiece, and so prevents the board touching the wall. This is very desirable where the meter is fixed in a damp cellar (in which case the fixing screws should preferably be japanned).

Various sizes of board will be required if different types of meter are used, but it is convenient to standardize boards as far as possible, and the following sizes have been found suitable for the meters enumerated :—

Size of Board.	Meters for which it is suitable.
1 ft. 1½ in. × 9 in.	Brush-Gutmann, Eclipse (B.N.R., N.R.) Electrical Co.'s (K.J. and prepayment). Hookham (1901), O.K. (and prepayment). Reason (and prepayment). ScheeferThomson (old type). Vulcan prepayment, Westinghouse.
9 in. × 9 in.	Eclipse (types C.R., F.E.G., and F.E.M.). Electrical Co.'s (R.A.), Ferranti (A. and C.C.) Mordey-Fricker (and prepayment). Thomson (old type, 5 amp.), Stanley.
1 ft. 4 in. × 9 in.......	Hookham (1897). Schallenberger, Vulcan.
1 ft. 6 in. × 5½ in.	Fricker Demand Indicator. Wright Electrolytic and Demand Indicator.
1 ft. 2 in. × 1 ft.	Electrical Co.'s (K.G.), Hookham (prepayment).
1 ft. 10 in. × 11 in.	Aron (metal cased).

It goes without saying that secure fixing of meter-boards is most important. With lath and plaster walls this is often difficult. Lath screws may hold a board firm or they may not, and plugging is out of the question. If, therefore, a solid wall can possibly be chosen it is far preferable. The plugging of walls is, however, often done in a very bad way. If a rough

hole is cut with a chisel, and a plug roughly made, wedge shape, driven into this, it is very liable to work loose, the taper of the wedge being the wrong way round. Blocks

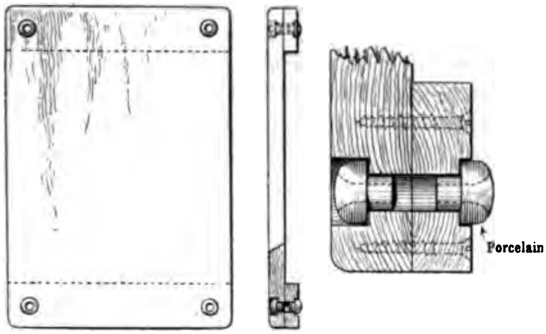


FIG. 203.—BACKING BOARD FOR METER FIXING.

tapering in the right direction let into the hole with cement have been known to work loose. With this method the block or plug is generally wet when put in, and shrinks on drying. In Fig. 204 a plug is illustrated which has given great satisfac-

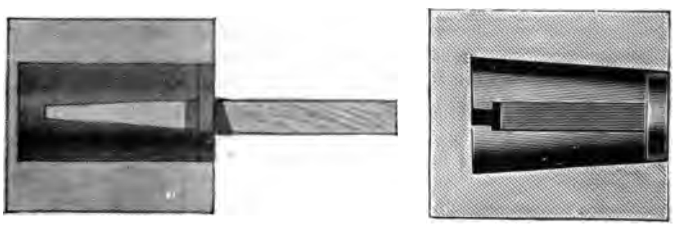


FIG. 204.—LIMPET PLUG IN WALL BEFORE AND AFTER DRIVING WEDGE HOME.

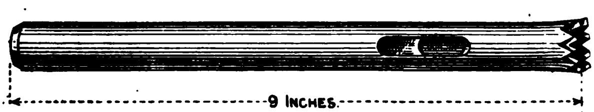


FIG. 205.—JUMPER FOR MAKING HOLES FOR LIMPET PLUGS.

tion, being easily fixed, and extremely firm when fixed. It is made by the Patent Plug Company, who also provide the jumpers for cutting holes of suitable size.

A round hole is cut the correct size with a jumper made specially for the plugs: this tool (Fig. 205) is held straight and hammered *lightly*, when a clean round hole is quickly cut, the depth of which should be the length of the plug. The dust is blown out of the hole, the plug inserted, and the wedge driven home, which operation cracks the back or solid end of the plug, compressing the sides against the sides of the hole at the back. Plugging a wall in this way requires no skill, and it is quite easy to plug glazed brick walls cleanly if the jumper is held with its end flat on the wall and the hammer used lightly.

The next point in connection with installing meters is their correct connecting up. Where many types are used the correct connections are apt to become confusing, as each type requires a different arrangement of the mains. In some cases the polarity of the ends inserted is the important point, whereas in others the polarity is of no consequence, but the choice is between "station" and "house" mains.

The following shows how the type of meter affects the connections:—

Alternate-current Ampere-hour Meters.—Connections immaterial.

Continuous-current Ampere-hour Meters.—Essential that the positive end of the bight be connected to the proper terminal, irrespective of whether it be the "station" or "house" end.

Continuous-current Watt-hour Meters, and Ampere-hour Meters having a Shunt Circuit.—As above. The bight should also be in the correct main, so as to make it possible to insert the "station" main into the proper terminal also.

Watt-hour Meters (two-wire) both of the Induction and Non-inductive Types.—Essential that the "station" end of the bight be connected to the proper terminal, irrespective (on continuous-current) of whether it is the + or − end of the bight.

Watt-hour Meters (three-wire).—Essential that the two "station" ends and the two "house" ends of the outers are connected to the proper terminals.

The result of a wrong connection in two-wire meters is to cause the meter to record backwards or not record at all. In three wire meters, if one main is properly connected and the other reversed, the meter will not record at all; if both mains are reversed the meter will record the wrong way, and if the two station ends are inserted into the terminals forming the

ends of one of the main coils, a troublesome short-circuit will be the result immediately the current is switched on. It is a good plan for each meter fixer to have a rough sketch of the connections of all the meters he is likely to be called upon to fix, and on these sketches arrows showing the correct direction of turning of the moving parts of motor meters, leaving no excuse for a meter being left by the fixer wrongly connected into circuit. Where different types are distinguished by a "Code letter" (*see* Chapter XV. on bookkeeping), the sketches of connections are

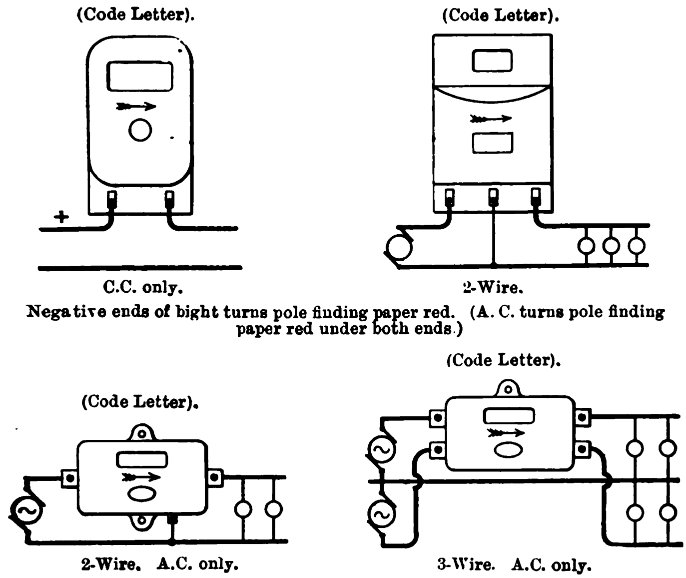


FIG. 206.—DIAGRAMS OF CONNECTIONS FOR METER FIXERS' USE.

preferably arranged in alphabetical order in a small pocket-book. Examples of the sort of sketches which have been found satisfactory in practice are given in Fig. 206.

Meters may be installed on either main of a two-wire system, but in three-wire systems (both alternating and continuous) with earthed neutral, no meters should be connected up on the neutral.

It is apparent from Fig. 207 that if the meter M is connected in the neutral lead as in the house "A," and an earth occurs

on the house side of the meter (as at E), the meter will be partially short-circuited. If the meters are invariably connected up in either outer as at the house B_1 the earth will nota ffect the registration of the meter. (An earth occurring on the same main as the meter would in this case, of course, be a short-circuit.)

In connection with three-wire networks another point which —although not relating to the erection of meters—is important, as far as their proper working is concerned, is the reversing of the ends of the meter bight in the case of continuous-current ampere-hour meters in all cases where the house is connected on to the other arm of the network. For purposes of balancing it is sometimes necessary to do this. In Fig. 207, if B_1 is put on to the other arm as at B_2, it is necessary to connect the meter

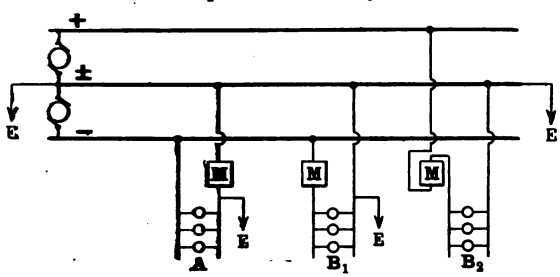


FIG. 207.—INSTALLATION OF METERS ON THREE-WIRE NETWORKS.

up as at B_2—that is to say, to reverse the ends of the meter bight, otherwise the meter will work backwards, if a motor meter, the reading being gradually wiped out. Electrolytic meters will also cease working unless their connections are rearranged.

Where meters are clamped, the next thing to be done after the connections are made is to unclamp the moving portion of motor meters provided with clamping gear, after which the terminal box cover should be replaced and sealed up. If the service is on, every meter should be tried for starting with, preferably, a lamp of the installation, or with a portable lamp should it not be convenient to switch on the former. If the meter does not start when the lamp is switched on, the first thing to look at is the clamping gear, for the unclamping may not have been performed completely. The next thing to look at, in the case of watt-hour meters, is whether there is any break

in the shunt lead to the meter, or whether this has been taken off the same main as that to which the main coils are connected. By means of the portable lamp lead this is easily tested by touching one end of the lead on the main and the other lead on the shunt terminals, when the lamp should glow.

The circuit having been proved in order up to the meter terminal, it is easy to see if the current is flowing through the meter shunt by disconnecting the shunt lead at the meter terminal and "flipping" to see if the current spark is present. Owing to the fact that in testing watt-hour meters the shunt of the meter is usually disconnected from the main terminal, it may in some cases not have been replaced. The fault is easily remedied if the meter fixer knows what to look out for.

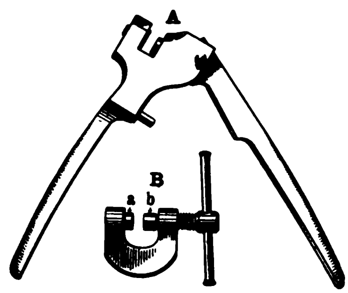


FIG. 208.—SEALING-TONGS AND CLAMP.

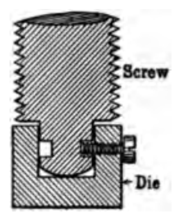


FIG. 209.

The usual method of sealing meters is by means of lead seals through which wires are passed, the seal then being squeezed by means of sealing tongs which contain a die or dies. The general form of sealing tongs is seen at A (Fig. 208), although different forms—some of which are over 2 ft. long—are used. Those illustrated at A (Fig. 208) are 8½ in. long and weigh 2¼ lb. With a view to reducing size and weight the sealing clamp B (Fig. 208) was designed and found to answer equally well. The difference in size is seen in the figure, and the weight of the clamp is only 8 oz. The one die, *a*, is screwed into the frame, whilst the other, *b*, is supported by the screw, as in Fig. 209, so that when pressing on the seal it does not turn as the screw is tightened.

Each meter-fixer should have his own sealing tongs or clamp, the dies of which bear a special number. Meters sealed in the department before being sent out should be sealed by a

punch or clamp having special dies. It then becomes possible to trace who last sealed the meter or whether it has been opened since its erection.

Penalty plates are sometimes used with a view to the prevention of the breaking of seals by unauthorised persons. A penalty plate is simply a brass stamping with an eye into which the lead seal is passed before being pressed. The plate usually bears an inscription resembling that in Fig. 210, in which a seal and plate are seen before and after punching.

In the case of apparatus such as prepayment meters or demand indicators, which are periodically opened for the pur-

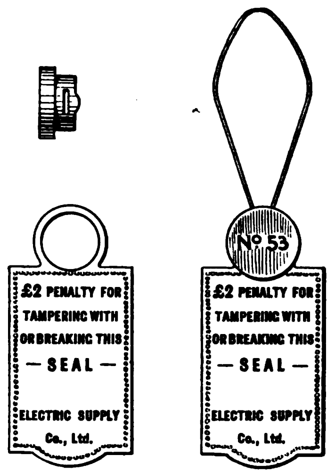


FIG. 210.—SEAL AND PENALTY PLATE.

pose of collecting the coins or resetting to zero, a more convenient way of sealing is by means of a padlock seal, such as the Tourtel or the Chubb. In these padlocks the hasp when pressed home is self-locking, and it also locks a small door in front of the keyhole. The keys are all similar. In front of the keyhole a paper ticket bearing a special number is placed before closing the lock. This ticket being placed over the keyhole, and held in position by the door already referred to, it becomes impossible to open the lock without breaking through the paper. If the paper is broken this is at once apparent to the inspector.

METER READING.

Accurate meter reading is a great desideratum, and although readings, as a rule, are not difficult, the meter reader should, nevertheless, always be on his guard, for he is sure to come across some in which he is very apt to make a mistake. With ordinary dial trains, such as those illustrated in Figs. 211, 212, 213 and 214, the difficult readings occur when one or more of the hands turn through the zero. In this type of counting train the spindles carrying the hands are geared together by means of wheels and pinions having a 10 : 1 ratio. In the examples illustrated each hand makes one complete revolution, while the hand next to it to the left passes through one-tenth of a revolution, and alternately the hands turn clockwise and counter-clockwise, the spindles being directly geared. In some types of dial-counting trains all the hands turn in a clockwise direction, additional spindles, carrying toothed wheels, being inserted between each hand-bearing spindle and the next. Another type of pointer dial train which makes all the hands *appear* to turn in the same direction has been brought out by the International Electric Co. In this the hands and dial discs alternately are stationary or revolve—that is to say, if the first pointer revolves the second is stationary, the disc of this one revolving, and so on. If meters having trains of these different types are used on the same system, the meter reader should be warned of this fact. In reading meters having dials of either of these types, it is perhaps easier to take the reading backwards, *i.e.*, to read the units dial first, then the tens, and so on, the general rule being to take the lowest number when a hand stands between two numbers. When a hand is near zero, however, the next hand higher up the train is very nearly over one of the divisions of its dial, and the correct reading for the latter is determined by the position of the former. In Fig. 211, for example, the units hand has just passed through zero, consequently the 10 hand must be taken as reading 1. Had the units hand been between 9 and 0 instead of between 0 and 1, the correct reading of the 10 hand, even in the position in

which it is seen in the figure, would have been 0, the 10 hand having passed the 1 mark before it ought to have done so. Thus in the first case, Fig. 211, the units hand would be taken as reading 0, the 10 hand 1, the 100 hand 9, the 1,000 hand 8, and the 10,000 hand 9, giving a reading of 98,910 B.T. units.

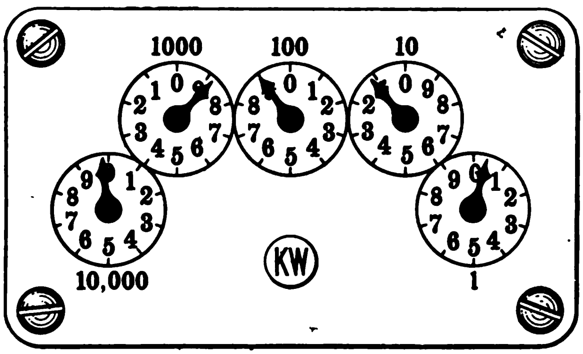


FIG. 11.—READING 98910.

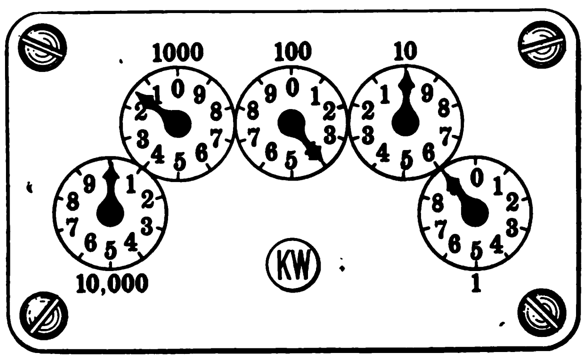


FIG. 212.—READING 01399.

Possible inaccurate readings would be 09,910 and 99,910, for which there would be no excuse, as the hands are not out of place. In the dial shown in Fig. 212, the correct reading of which is 01,399, the 100 hand is slightly out of position, having passed the 4 before its time, and a careless or inex-

perienced reader might take the reading as 01,499, making an error of 100 units; he might also take the reading as 01,409.

Figs. 213 and 214 illustrate the effect on readings of the dial plate being placed so that the hand carrying spindles are eccentric.

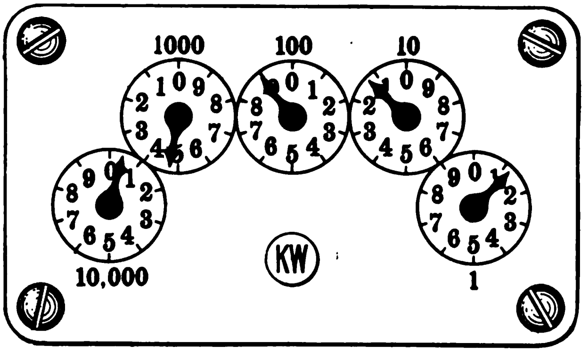


FIG. 213.—READING 04911.
(Spindles eccentric.)

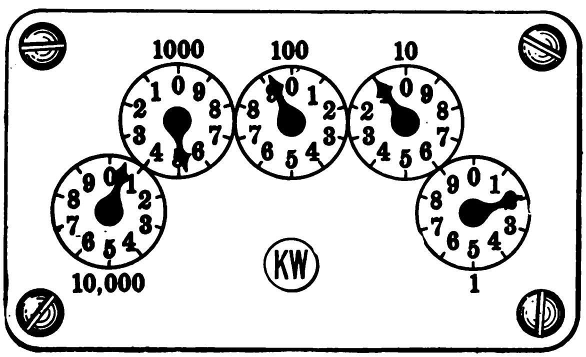
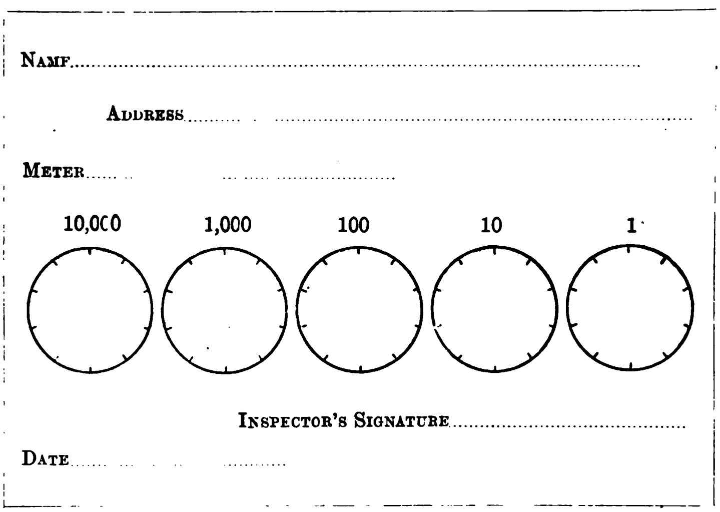


FIG. 214.—READING 04912.
(1000's Hand bent.)

In Fig. 213 the dial plate is too far to the right and in Fig. 214 it is too far to the left. With the exception of the reading of the units hands the two readings are the same—viz., 04,911 and 04,912; but it will be noticed that the positions of the various hands are slightly different in the two figures. The

hands are not in their correct positions in either figure, being too fast or too slow owing to the eccentricity of the dial plates.

In Fig. 214 also the effect of a bent hand is shown in the case of the 1,000 hand. This hand has passed the 5 mark, but a glance at the 100 hand shows that the 1,000 hand is out of position, for if the reading of two hands under consideration be taken "59," the 1,000 hand should be almost on the 6 mark. Being much nearer the 5 than the 6, it should be taken as reading 4 (the 100 hand reading 9, as it does).


NAME..........

ADDRESS..........

METER..........

10,000 1,000 100 10 1

INSPECTOR'S SIGNATURE..........

DATE..........

FIG. 215.—CARD FOR NOTING POSITIONS OF HANDS WHEN READING IS DIFFICULT. (5in. by 3in.)

It is a good plan to provide meter readers with cards (as shown in Fig. 215 above), on which are printed blank dials. If on his rounds the meter reader comes across a difficult reading, or one which he is not sure of, he can then fill in the positions of the hands. It then becomes possible to determine what the reading should be without a second visit to the meter, thus saving time to the staff and annoyance to the consumer.

From the meter reading point of view cyclometer dials are much simpler than the pointer dials. Difficult readings, however, are found with this type of dial when the numbers are

changing, as for example from 59 to 60, or, say, from 4,999 to 5,000, when the tops of the lower numbers and the bottoms of the higher ones are visible through the slots of the front plate. With the springing number counting trains the intermediate positions do not occur, and these are therefore the ideal type of counting trains from the reading point of view, as with them mistakes in reading can only be due to great carelessness on the meter reader's part.

Readings of meters such as the Wright electrolytic are fairly easily taken, but owing to the fact that in some sizes one division of the scale is equivalent to one B.T.U., whilst in other sizes a division represents two B.T.U. or more, a mistake of a few units may easily be made. In such meters of this make as have the syphoning tube graduated in divisions equivalent to four or five B.T.U., and the whole range of the tube equal to 200 B.T.U., the readings become more difficult, and an error of 100 units is liable to be made unless great care is taken, which tends to lengthen the time taken in reading.

The reading of every dial, figure, or tube, as the case may be, should always be noted by the reader, *i.e.*, if a meter is found to be indicating only six units, and is provided with dials up to the 1,000's, the reading should be written down as "0006," and not simply as "6." In the case of the Wright meter, of the syphoning type, having a tube indicating up to 100 B.T.U. and a second tube indicating up to 1,000 B.T.U., the above reading should be written down as 006. A reading entered in this way infers that all the dials or tubes were examined by the meter reader.

CHAPTER XIV.

METER CLEANING AND REPAIRS.

On the return from the consumers' premises of meters which have been out some time it will often be found that, although in good repair, such meters may be, and probably are, more or less dirty. After making a "test as returned," from which it may be found that the meter is slow at low loads, due to the increased friction caused by dirt, it becomes necessary to overhaul the various parts and thoroughly clean them.

Where the covers are not airtight they can be made more dust-proof by applying vaseline at the joint between cover and case; the vaseline catches a lot of the dust which would otherwise enter the meter. Another point which should receive great attention before a meter is sent out on service is the joint between the glass of the window and the cover. These glasses should be bedded on putty, care being taken that no holes are left.

Unless very dirty, there is usually no need to take the instrument entirely to pieces for cleaning. The wheel train is removed and perhaps the main moving part. Then an air blast, preferably from a foot blower, will remove the dust from positions which cannot be got at with brush and duster. The wheel train should be taken to pieces, and all bearing holes in the plates cleaned with peg wood. These should be oiled after cleaning, using a clean pointed piece of peg wood which is just damp with the best clock oil. The slightest film of oil only should be allowed to remain. The pivots should all be cleaned with pith, and the teeth of the wheels brushed with a stiff watch or clock brush. If the teeth are very dirty, it may sometimes be necessary to soak the wheels in paraffin before brushing, or it is sometimes sufficient to moisten part of the

brush with paraffin and finish off with the dry portion. Peg wood can also be used for the removal of dirt from the teeth, but on no account should they be scraped with a metal instrument, such as a needle or small brooch. If at all burred, it is sometimes possible to file up a tooth, for which a tooth-cutting file, as used by clockmakers, should be employed. The bearings of the main spindle are cleaned similarly, pith being used for the jewel, which should also be felt with a sharp needle to ascertain if it is rough or cracked. If not found absolutely smooth it should be replaced by a good one, and the pivot or spindle base repolished or replaced.

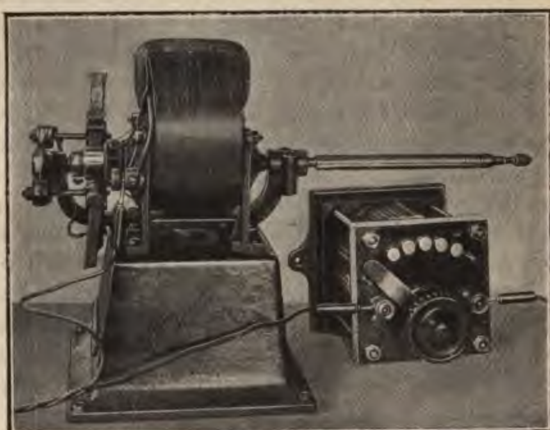


FIG. 216.—PIVOT POLISHING MOTOR.

In many meters the pivot is screwed into or on to the bottom of the main spindle, and can be easily removed by means of a key. In such cases there is no need to remove the main spindle, which often means taking the meter to pieces. The practice of using a separate pivot greatly facilitates its examination and repolishing. A polishing head or small motor should be provided with a chuck capable of taking the pivots or spindles, in which case the spindle of the headstock should be hollow. A motor fitted with a hollow spindle and chuck for this work is shown in Fig. 216. The chuck is fixed on the end of a tube and will take most meter spindles. The work necessary to bring the pivot up to the desired polish depends

on its condition. If at all flat, it should be rounded, using a piece of fine grain Arkansas hone, after which various grades of "blue-black" paper (which is obtainable at any clockmaker's tool warehouse) and a pivot burnisher are used. If finished off with crocus powder and oil a high polish is obtained. A strip of bell metal, oiled, is dipped into the crocus powder, of which a certain amount sticks to the strip, which is then used as a file would be, while the pivot is turned at a high speed. The pivot should be examined in a good light through a magnifying glass. The initial friction and wear depend so largely on the polish of the pivot and jewel that great attention should be paid to these precautions. The most durable point seems to be a spherical one. When a ball takes the place of the pivot, a new ball should be inserted to replace the one which has been running on the damaged jewel.

The footstep jewels are usually sapphires, which rank in hardness next to the diamond. If only rough, and not cracked, they can be repolished at a reasonable cost by workers of precious stones. Those which are cracked are useless and must be replaced by new stones.

In meters having commutators, the condition in which the commutator keeps depends principally on the sparklessness of the brushes. If these spark the commutator soon becomes pitted and rough, whereas if no sparking takes place they will last for years in good condition, if precautions are taken to avoid, as far as possible, dust entering the meter. External vibration is probably the chief cause of sparking; it therefore follows that, in order to avoid this source of trouble, the brushes must have as little weight at their free end as possible to prevent pendulum action. With a light brush, also, a weaker spring can be used. It is the Author's experience that wire brushes give the least trouble. The point of contact of a circular wire on a cylinder being very small, the number of independent points of contact can be increased without causing the brush friction to be greater than it would be if one or two flat brushes were used, and the more independent points of contact there are the less is the chance of sparking taking place. Wire brushes, moreover, when separated, seem to push aside dust particles, thus keeping the commutator clean in the path of each wire. With a view to testing the life of wire brushes, a meter has been run

with its cover off in a very dusty situation on a 220 volt supply with a current of 0·05 ampere in the commutator circuit. Its speed has been varied, sometimes exceeding 100 revs. per min., and it has also occasionally been stopped. The brushes are covered with dust, but the commutator has clean lines where each brush touches it and is very dirty at other points. There has never been the slightest visible spark, although the number of revolutions made by the commutator under these abnormal conditions exceeds 25,000,000, an equivalent to over 25 years' working on an average consumer's premises. In this test each brush consisted of four No. 22 standard silver wires, supported in pairs by independent phosphor-bronze strip wound as a spiral spring.

Commutators which have not been damaged by sparking require only a rub with a piece of linen tape, which should be slightly narrower than the commutator. The tape is passed round the back of the spindle, and slipped between the brushes and commutator. The two ends of the tape (which is about 12 in. to 18 in. long) are held one in each hand in the front, and alternately pulled backwards and forwards, thus turning the commutator and cleaning all the segments. Should the commutator be pitted, narrow strips of "blue-black" paper should first be used in the same way as the tape, always finishing off with the finest ("0000"), after which it is finally polished with tape. When such treatment has to be resorted to, particles of silver dust may become lodged between the commutator bars. These, if not removed, may short-circuit sections of the armature; they should, therefore, be blown out by means of bellows, or a piece of peg wood, tapered to fit between the commutator bars, may be passed down between each segment. The brushes should be removed from the meter and cleaned, if of strip or flat silver, by means of the same materials as used for commutators. Wire brushes require renewing if found to have been sparking.

Wire brushes are easily made out of hard-drawn "standard" silver wire, which can be obtained in any wire gauge size. This wire is straightened by passing short lengths through a spirit flame, the ends being gripped by pliers. After a little practice it can be straightened in this manner and still retain the requisite spring. Pure silver is too soft for this work

Other mechanical defects in meters comprise bent spindles, bent discs, broken covers, broken or defective wheel trains, bent hand-carrying spindles, broken or blackened dial plates, broken screws in terminals, broken glasses, &c. Main spindles can often be straightened by tapping with a boxwood mallet, or, if bent near the worm, by pressure until they become true. Discs can also be trued if fitted on a mandril and placed in the lathe. Other mechanical defects are remedied by replacing the parts with new ones, which can generally be obtained from the makers, and of which it is convenient to keep small stocks so that the repairs can be finished off without delay. In large undertakings it will often pay to make several parts, but little can be done without a suitable lathe, such as a Lorch or Boley instrument maker's lathe. With such a tool much can be done in the way of repairing or improving meters. Where screws are required the B.A. standards will be found useful, and a set of B.A. taps and dies shonld be provided. Glasses for the renewal of the windows should be stocked in larger quantities, as these are easily broken. A meter should never be allowed to remain in stock with a broken glass, for it so soon becomes dusty, and would require a further cleaning before being sent out.

In the case of motor-meters containing mercury, it is sometimes advisable to replace the old mercury with new pure mercury. If the old be found dirty the bath should be opened and cleaned before filling with the new mercury.

Electrical defects principally consist of short-circuits of main or shunt coils, or resistances, breakages in these circuits, and breakdowns of the insulation to case. Short-circuits of the main coils are generally caused by considerable overloads charring the cotton insulation of the wire or strip, and meters which have been sufficiently overloaded to create such short-circuits indicate the fact by the outward appearance of the coils. The main coils may sometimes be short-circuited by the metal clips by which they are supported, but this defect is rare, as the clip must have pierced the insulation in two points to produce it. A leak to case caused in this manner is more frequently met with. These defects are easily localised by testing between the various parts with an ohmmeter, or a detector and battery can be used if the resistance of the fault is low enough. Where a leak to case or short-circuit of a

main coil is caused by the supporting clip the insertion of a piece of mica between clip and coil will remedy the defect, but main coils which have been overloaded sufficiently to char the insulation should be replaced, as they are unreliable, even if apparently unshort-circuited. The Author has known cases where such coils, apparently in working condition when cold, have become partially short-circuited when heated by the passage of full-load current for some time. The meter running abnormally slow, coupled with a low-voltage drop across the main coils, is an indication of short-circuited main coils.

A partial short-circuit in the shunt may be indicated by the meter speed being very high, in which case the shunt current will be above the normal. This defect most frequently occurs in meters having non-inductive resistances wound double on bobbins. Where the resistance is wound on more than one bobbin, the faulty bobbin can often be traced by feeling the wire on the several sections after the shunt circuit has been energised a little while. The shorted bobbin will be cold and the sound ones warmer than usual. If no difference in the temperature can be noticed in this manner, it becomes necessary to test the resistance of each section or bobbin, either by the Wheatstone bridge or potentiometer methods. The latter is preferable, as short-circuits in these bobbins may be intermittent, only appearing when the coil is hot. Faulty bobbins should be replaced by new ones of the same resistance and the old ones destroyed.

Where meters have wound armatures and commutators, short circuits may occur between adjacent commutator bars, and before an armature is changed it should be ascertained whether the fault is in the commutator or in the armature. Faults of this description can be detected by the unevenness of the speed during a revolution at low loads. They can also be found by measuring the torque for different positions of the armature. Should the torque be zero in any position, it is evident that there is a break on one or the other of the coils connected to one of the bars underneath the brushes.

If a suitable ammeter—*i.e.*, one having a range 0 to 0·05 or 0·1 ampere—be inserted in the shunt circuit, and the armature turned slowly, a jump will be noticed in the reading of the ammeter if the armature or commutator is short-circuited.

Owing to the high resistance in series the jump will only be very small, but if the ammeter is connected up in series with the armature on a low voltage sufficient to produce the normal current in the circuit, the jump becomes very marked. It is a good plan to test all new armatures in this manner before they are put into meters.

On a short-circuited armature being found, the spindle and armature complete are removed from the meter and all the leads unsoldered from the commutator bars. The commutator can then be tested between bars for short-circuit. A handy tool for this work is made by soldering pieces of small flexible lead to the eye ends of two thick needles. The needles are then separated by a thin strip of vulcanized fibre or other insulating material and the whole bound round with tape, as in Fig. 217. The thickness of the fibre should be such that the points of the needles are separated by about the pitch of the commutator segments. The ends of the flex can be connected through an 8 c.p. lamp or voltmeter to the 100 or 200 volt supply, when faulty insulation between bars is easily detected; or a detector and battery or ohmmeter can conveniently be used. The air-space between two shorted bars can be cleaned with a pointed piece of peg wood, which is also pushed down behind the insulating band which holds the bars, and should the short-circuit be due to silver dust this will often remove it. By applying the current for some time (at 100 or 200 volts through a lamp) a fault can sometimes be burnt out without damaging the commutator if the peg wood fails to remove it.

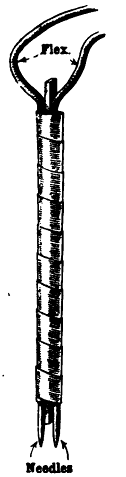


FIG. 217.—TOOL FOR TESTING INSULATION BETWEEN COMMUTATOR BARS.

This somewhat crude method of removing faults has often been used with success in locating and burning out leaks from commutator to main spindle, one pole of the supply being connected to the case or spindle.

Owing to the fineness of the wire used in meter armatures and the consequent difficulty of making contact with the ends of the coils, it is convenient to provide for this purpose a pair

of spring clips into which the wires from the armature are placed after disconnecting them from the commutator. The clips may be conveniently mounted on a stand and provided with terminals for the testing leads, as in Fig 218. The ends of each armature coil are successively pinched in the clips and tested.

A short-circuited coil is rarely found, and usually if any trouble is due to the armature itself it is caused by a break in a coil. Careful examination of the outside of the coils will determine whether any injury has been caused by a blow or

FIG. 218.—STAND FOR TESTING ARMATURE COILS.

the slipping of a screw-driver, in which case several breaks may be found, and it would be cheaper to replace the damaged armature with a new one. It is very difficult to unwind and rewind an armature with the same wire, but one or two coils can be unwound and replaced, and should a break occur in one of the upper coils it can be unwound, repaired and rewound; or new wire can be put on in the place of the old from the point where the fault is found. Breaks are frequently found in the ends of the coils where they are taken up to the commutator bars, and these ends should be carefully examined

when detached from the commutator in the first place. The Author employs a special chuck for holding armatures of the Duncan, Thomson or Vulcan type when unwinding or rewinding. This chuck, which is suitable for mounting on a polishing head or on a phonograph motor, is illustrated in Figs. 219 and 220. Fig. 219 shows a front and side sectional elevation, whilst in Fig. 220 an armature is seen mounted in the chuck. The

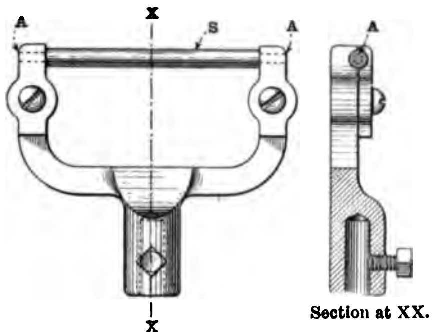


FIG. 219.—CHUCK FOR ARMATURE WINDING.

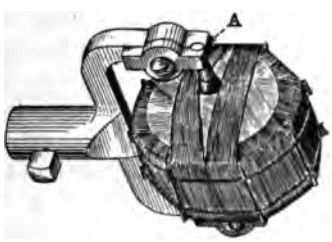


FIG. 220.—VIEW OF ARMATURE CHUCK WITH ARMATURE MOUNTED.

armature is clamped in the usual way, on a spindle, S, which is then gripped by the jaws at A A. The armature is centred by sliding it up and down the spindle S, after which it is clamped, and the spindle can then be turned when its clamps are loosened until the space on which the coil is to be wound is in position. By turning the armature and spindle bodily other coils are easily brought into position without further centreing being necessary.

Very often the armature is clamped to its spindle by two screws in the centre of the spider frame, the heads of which

are got at by a small wire driver passed between two adjacent coils. Other armatures are clamped by a taper nut, which is run up a split hollow taper screw underneath the armature. The Eclipse armature coils are former wound before being bunched together.

The armature to be unwound is soaked in methylated spirit to soften the shellac, and the coil being unwound should be frequently brushed with a camel hair brush dipped in methylated spirit to keep the shellac soft. The speed must be extremely slow, and a revolution counter should be fixed to the other end of the lathe head spindle to ascertain the number of turns, in order that the same number may be wound on again.

For winding non-inductive resistances, compounding coils and armatures, a phonograph motor is perhaps the most suitable motor to use, as its speed is so easily adjusted and, its power being small, breakages of the fine wires used in these operations are avoided.

Another fault in meters having non-inductive shunt circuits is that the non-inductive resistances may sometimes break. The faulty section, when found, can be unwound, mended and rewound. It should, however, be ascertained that the wire has not become brittle, in which case the whole resistance should be replaced by a new one.

In induction motor meters breaks may arise in the shunt circuit. When a faulty part of the circuit is found and is replaced by a new one, such as a new coil on the shunt magnet or a new impedance coil, the resistance is of little consequence compared to the self-induction. If, therefore, any coil is rewound the number of turns and the air-gap should be the same as before the repairs.

Repairs to electrolytic meters, such as the Bastian or Wright, are either very simple or those which can only be done by the makers of the meter. They chiefly consist of replacing broken glass vessels. A new glass vessel means a new scale. The shunt circuit of the Wright meter may break, and if the meter fails to register this circuit should be tested. The break will probably be found to be either at one of the clips or possibly at the joints, with the wires coming out of the glass vessels. Should the break be in the resistance bobbin, the wire should be unwound very carefully and the same wire replaced, its

length being unaltered, otherwise the temperature compensation may be affected. The mercurous solution in this meter has proved to show a marked tendency to crystallize, which is a very objectionable feature, as the crystals formed interfere with the working of the meter by obstructing the tubes. The makers are experimenting with a new liquid in which this crystallization will not take place. In the Aron meter, in addition to breaks in the shunt circuit, there is the liability of the main spring breaking, as also the hair spring which drives the commutator. A main spring is easily replaced, and can be done in situ if necessary, as there is no fear of the calibration being affected. In examining an Aron meter after cleaning special attention should be paid to the various pins and stops, which should all be screwed home tightly. The reversing gear works suddenly, and if this point is not attended to trouble is very likely to be caused by the pin and stops working loose with the jarring which they receive.

The winding gear should also be worked by hand, to see that it is quite free and that the ratchet and pawl are working properly. Faults or breaks in the shunt circuit are localised as in any other meter. On the switching on of the shunt current the winding gear should immediately wind up the spring and both pendulums start oscillating. If neither move, most probably there is a break in the shunt circuit; if only one starts, the pallets of the one which remains stationary are probably dirty or not properly adjusted. The pendulums should be tried for starting several times by switching the shunt current on and off or by holding them in the vertical position and releasing them without giving them any push-off.

CHAPTER XV.

METER BOOK-KEEPING.

The problem of keeping an accurate record of the dealings in meters is a most important one, and necessitates a system of book-keeping which prevents, as far as possible, the chance of errors creeping in.

Records are necessary, in the first place, to show the transactions between the makers of the meters and the undertaking, and, in the second place, to show the distribution of the meters over the area of supply and the stock. In addition to these important branches of the book-keeping of a meter department are the following: (*a*) Records of tests (both in the test rooms and in situ), (*b*) repairs and maintenance, (*c*) meter readings and accounts. There are probably many systems of meter book-keeping in use by the various undertakings, the records in some being kept in books alone, or entirely on the card system, or a combination of books and the card system may be employed. The latter, in the Author's opinion, seems to be the safest and easiest. The day books and ledger are best in book form; whilst the street index and stock index in book form are almost impossible, owing to the constant changes taking place, and the card system for these and for meter reading is perfect.

The transactions with the makers can be kept in three books —viz., (1) Meters on order and delivered, (2) Defective meters book, (3) Meter parts and sundries on order and delivered. Suitable forms of ruling for these three books are seen in the following Forms 1, 2 and 3; a suitable size being 10¼ in. by 8¼ in. On the lefthand sheets the particulars are entered at the time of ordering or the return of a defective meter, and the spaces on the righthand sheets are filled in as the goods are delivered. In the Meters on order book the entries are intended to be made

so as to leave enough room on the right-hand sheet to enter the number of every meter received against the order. If the index to this book be arranged so that the makes are alphabetically entered one on a page, and the sizes dealt in placed in order, easy reference can be made.

In order to keep a complete control of the meters, it is almost essential to give each meter a serial number, but in order to keep the numbers as small as possible and to be able to distinguish different makes, it is a good plan to start a fresh set of numbers for each make, giving a different code letter to each make, and so numbering the meters that the code letter is always quoted; thus, "No. A 59," "No. B 108." In this way the quantity of meters of each make on the books is always the highest serial number in that make. In some cases the meters are given their serial number immediately on delivery, but as some are sure to have to be returned to the makers, owing to defects or damage, it is more satisfactory to give them their serial numbers after they have passed the first test. If this method is adopted any meters returned to the makers (which are sometimes replaced) do not cause gaps in the numbering. A further advantage of numbering the meters after test is that they are sent out, or should be sent out, on to circuit in numerical order in their respective sizes, and if any number be missing it should at once be found out and investigated.

Form 4 illustrates a form of ruling of a test book for motor meters. The headings need no explanation, but it will be noticed that two columns are left for meter number. The makers' number is only inserted in the case of new meters, and those which pass the test are immediately given a serial number which should be plainly marked on the meter, preferably on the dial. (It should be remembered that meters while out on circuit sometimes get painted; it is therefore not safe to simply paint the serial number on the case.)

From the test books (one of which should be provided for each make of meter used) the numbers are entered in serial order in the meter index book, Form 5, those meters which are not ready to go on circuit receiving no serial number. Such index books have been found to be extremely useful, and one should be kept for each make of meter.

There are four sets of columns across the double page, giving room for entries of the folios in test book, outwards book, and inwards book four times, after which the line is filled up. The meter is then re-entered on the first vacant page of this index, the second folio in index being put in one of the columns provided, so that, when the line of a certain meter is filled up, its second, third or fourth entry in the index is always seen at a glance.

At the time when the meters are entered in the index they are also entered in the ledger (Form 6); but in this book a whole page is reserved for meters of the same size and make. This book is indexed, the number of the various pages as they are started being entered against the particular size in its index, and the numbers of the preceding and succeeding pages devoted to the particular size entered in the spaces provided in the top right-hand corner of the page, so that a size can be easily traced through the book. The addresses to which the meters are sent are entered when the meter is booked out, at the same time being entered in the meters issued book, Form 7, in which all sizes are together, the entries being made one under the other as the meters are issued. This book, as also the meters returned book, Form 8, are, in fact, day books. It is convenient to provide columns in the meters issued and meters returned books for ticks to indicate that the entries have been made in the ledger, index and stock sheet, and also to show that the card index is cleared. The meters returned book should also be provided with columns for noting whether the meter was returned clamped, and for the initials of whoever checked the number, reading, &c. The readings of meters as returned are most important, and should be checked, as disputes may crop up a long time after meters have been returned.

A most important point in connection with meter book-keeping is to prevent all chance of a meter going out without any record being kept of its issue, for such a meter would not find its way into the meter-reading books, in addition to causing endless trouble at stock-taking time. By entering the meters in the ledger as tested, and referring to this book and selecting the first number against which no address has been inserted, an error of this kind is at once apparent if the meter

is not found in stock. Should the meter not be found, the next one is, of course, sent out, leaving a gap in the ledger, and the whereabouts of the lost meter can be traced at once. It is much easier to investigate such a loss at the time than a month or so afterwards. The stock sheet (Form 7), giving, as it does, so much information in a small space, is well worth the trouble of keeping. Reference to this sheet enables one to readily ascertain the rate at which meters of the various sizes are being issued and returned, and, therefore, to estimate the quantities of meters to order. These sheets are made up once a week, at the end of the year, and at such other stock-taking times. Two columns, (*a*) and (*b*), are provided for meters received, to separate those received from the makers, or new meters, from those received from consumers, or returned meters. Column (*c*) shows the total meters of the size and make on the books, and columns (*e*) and (*f*) their distribution.

The entries when made should be checked thus:—

$$c = e + f = c \text{ (previous entry)} + a.$$
$$e = e \text{ (previous entry)} + d - b.$$
$$f = f \text{ (previous entry)} + a + b - d.$$

For the purpose of keeping a hold on the meter stock and the meters on consumers' premises the card index system can hardly be dispensed with. The stock changes day by day, and at any time it is necessary to be able to quickly ascertain not only what is in stock, but also how the stock is standing—that is to say, how many meters are ready for test, tested, being repaired, &c. Two forms of card are given, 10A and 10B, for the stock card index, the former being recommended. Each meter as it is delivered from the makers has a card made out for it, the makers' number and other particulars being filled in. The card is then put in its proper place in the stock drawers. If the stock index is divided up by guide cards, first into makes, then into the following five divisions: (1) Ready for test, (2) Away for repairs, (3) Repairing and cleaning, (4) Meters not to be touched, (5) Tested meters—each of these divisions having other guide cards separating the sizes—all the information required is obtained by consulting this stock index. In each subdivision the cards are inserted in their proper place, so that the meter numbers are always all in order.

It is a good plan to use different coloured cards for the different makes of meter employed, for it then becomes noticeable if a card is inserted in its wrong place—*i.e.*, amongst those of another make. If card 10A is used, the stock index and street index forms one cabinet, separate drawers being used for the stock portion. When a meter is booked out, its card is taken from the stock drawer—where it ought to be found in the "tested" division. The address to which it is being sent is written on the card, and the latter placed in the street index portion. Here a guide card is provided for each street, these being arranged alphabetically, the cards, of course, being arranged according to the numbers of the houses. On the return of a meter the card is taken out of the street index, the date of its return entered against the address in the column provided, and the card placed into the stock index in the proper division (between the higher and lower number). Where a street index is not kept, card 10B may replace 10A in a stock index. This card, if printed on both sides, may be used eight times to represent different meters of the same make, one of the vertical columns being filled each time, the previous column being ruled through when the card is taken out of the index as the meter is booked out. For meter reading the card 11 is useful. These meter reading cards are made out from the meters issued book and placed in a cabinet in which they are kept, except at meter reading times, when they are tranferred in batches into covers, so forming meter reading books. They are conveniently arranged in the meter reading cabinet in street order.

To facilitate the making up of each meter readers' daily round, at meter reading times it is advisable to devote a portion of the drawer space to an auxiliary index, the guide cards in which are marked "Round 1," "Round 2," &c. A set of plain cards is used in this section, each bearing the name of one street (or in some cases it may be necessary to split up a street into several sections). All the street cards are then arranged in the most convenient order for the various rounds. If a large increase of meters to be read occurs on a certain round, slight rearrangement may become necessary and is easily effected if a card system is employed. The meter reading card index, and when necessary its auxiliary "round" index, are

kept up to date from the issues and returns books, new cards being introduced and those for returned meters being taken out day by day.

The records of tests in situ are also conveniently kept on cards, and it is as well to have two forms of cards of different colours to distinguish between those tests which are made owing to unexplained lowness of consumption, or under a system of periodical inspection, and those which are made owing to consumer's complaints or disputed accounts. The distinction is necessary owing to the fact that, whereas in the former class of test a meter may be examined and defects put right when necessary, in the latter class the seals should on no account be broken in case the consumer may subsequently have the meter tested by the statutory authority. It is a good plan to charge a nominal fee, 2s. 6d. or 5s., for a test in situ, where it is done at the request of the consumer who doubts the accuracy of his account, and where the meter is found on test to be correct. If the meter be found inaccurate the fee is not charged. Such a system tends to put a stop to a certain class of groundless disputed accounts, and at the same time enables the consumer to have his meter tested at a reasonable figure. Cards 12 and 13 give an idea of what is required for this work. The abbreviated headings of the columns indicate (1) Starting current, (2) revolutions in (3) seconds, (4) watts by meter, (5) constant K (or per cent. error of meter), (6) watts by standard instrument used in the test, (7) initials of tester, and (8) the number of the seals found on the meter.

A form of card suitable for the consumer's ledger if kept in card form is shown in Form 14. It is questionable whether the card system is preferable for this work, as a card is more likely to be lost than a page in a book, and it takes longer to make the entries on a card than on the pages of a book, the card having to be taken out and put back. In favour of the system, however, are the facts that the ledger in this form requires no index and may be kept in the same order as the meter reading cards.

FORMS FOR METER BOOK-KEEPING.

BOOKS.

CARDS.

---

*Copyright Forms.**

METERS ON ORDER.

(Pages numbered.)

ORDERS.									DELIVERIES.											
Date of Order.	Make.	Volts.	Amps.	Wire.	Quantity.	Requisition No.	Order No.	Goods Receipt No.	Date.	Meter Number.	Delivery Note No.	Date.	Meter Number.	Delivery Note No.	Date.	Meter Number.	Delivery Note No.	Date.	Meter Number.	Delivery Note No.

FORM 1.—METERS ON ORDER BOOK. (10¼in. by 8¼in. Pages numbered and Index.)

DEFECTIVE METERS RETURNED TO MAKERS.

(Pages numbered.)

Date returned to Makers.	Make.	Volts.	Amps.	Wire.	No. of Meter.	Requisition No.	Order No.	Goods Receipt No	Defects.	Date Returned from Makers.	Remarks.

FORM 2.—DEFECTIVE METERS BOOK. (10¼in. by 8¼in. Pages numbered and Index.)

* Books, Forms, &c., as set out in the following pages, can be supplied to order by the Publishers, 1, 2 and 3, Salisbury Court, Fleet Street, London.

METER PARTS AND SUNDRIES ON ORDER.

(Pages numbered.)

ORDERS.							DELIVERIES.					
Date.	Make.	Description of Parts or Sundries.	Quantity.	Requisition No.	Order No.	Goods Receipt No.	Date.	Quantity.	Delivery Note No.	Date	Quantity.	Delivery Note No.

FORM 3.—METER PARTS AND SUNDRIES ON ORDER. (Pages numbered and Index.)

METER TESTS. (Name of Type and Code Letter.)

Pages numbered.)

Size............. volt................ amp.............. wire. Tested on............. current at...............loads. Date...

Correct time for...........revs. at full load = secs. = "T." Standard Instrument used...

Meter Nos.		Testing Cons.	Revolutions.	Time for Revs. $= T_m$	Current (or Watts) by Stnd. Inst.	Meter Constant $K = \frac{T_m}{T}$	Starting Current.	Shunt Current.	Drop.	Reading after Test.	Insulation Resistance.	Remarks.
Serial.	Makers'.											

FORM 4.—METER TESTS BOOK (for Motor Meters).

METER INDEX.

Make.................... Code Letter............ (Pages numbered.)

Meter Nos.			Folios.				Folios.				Folios.				Folios.				New Folios in Index.
Serial.	Makers.	Size.	Test Book.	Outwards Book.	Complaints Index.	Inwards Book.	Test Book.	Outwards Book.	Complaints Index.	Inwards Book.	Test Book.	Outwards Book.	Complaints Index.	Inwards Book.	Test Book.	Outwards Book.	Complaints Index.	Inwards Book.	
1																			
2																			
3																			
4																			
&c.																			

Form 5.—Meter Index Book. (Foolscap. Pages numbered.)

Previous page........

Next page ....

(Name of Undertaking.)

METERS LEDGER.

(Pages numbered.) Make.......... Size....volt....amp.....wire.

Serial No.	Makers' No.	Name of Consumer.	Address.	District.	Date Fixed.	Reading.	Date of Test.	Date Returned.	Reading.	Date of Test.

Form 6.—Meters Ledger. (Foolscap. Pages numbered and Index.)

(Name of Undertaking.)

METERS ISSUED TO CONSUMERS.

(Pages numbered.)

Date Issued.	Name of Consumer.	Address.	Make (Code Letter).	Volt.	Amp.	Wire.	Number.	Meter Board.	Entered in Ledger.	Card Index.	Index.	Stock Sheet.

FORM 7.—DAY BOOK (ISSUES). (Foolscap.)

(Name of Undertaking.)

METERS RETURNED FROM CONSUMERS.

(Pages numbered.)

Date Returned.	Name of Consumer.	Address.	Make (Code Letter).	Volt.	Amp.	Wire.	Number.	Reading.	Seal Number.	Clamped ?	Entered in Ledger.	Card Index.	Index.	Stock Sheet.	Checked by.

FORM 8.—DAY BOOK (RETURNS). (Foolscap.)

(Name of Undertaking.)

METER STOCK SHEET.

Stock Sheet No.....for....volt....amp.......meters. Code letter..... Year.....

Date.	Received From Makers.	From Con-sumers.	Total in.	Sent Out	Total Out.	Stock.	Remarks.
	(a)	(b)	(c)	(d)	(e)	(f)	
1.1.05	—	—	500	—	400	100	
6.1.05	50	3	550	10	407	143	

FORM 9.—STOCK SHEET. (Foolscap.)

Meter No............. Size............ V............. A............wire.

(Maker's No............) Make.................. (Coin........ Rate........)

Names.	Addresses.	Dates Returned.

FORM 10A.—METER CARD. (5in. by 3in.)

Serial No.								
Maker's No.								
Volts								
Amps.								
Make								
Inwards ..								
Outwards..								
Maker's Ledger								

FORM 10B.—STOCK CARD. (5in. by 3in.)

(Name of Undertaking.)

Street..

Name..

No. and Size of Meter

Date.	Meter Reading.	Initials and Remarks.

FORM 11.—METER READING CARD. (3in. by 5in.)

Meter No......... **Size**......... **V**......... **A. Reading**......... **No**.........

Date.........

Address..

Complaint..

Stg. Ct.	Revs.	Secs.	W.M.	"K."	W.I.	Test by	Seals

Remarks..

FORM 12.—TEST IN SITU CARD. (5in. by 3in.)

COMPLAINT A/c TESTS.

No. ....

Meter No......... Size........ V......... A......... Date of test..........

Reading..

Address ....

Stg. Ct.	Revs.	Secs.	W.M.	"K."	W.I.	Test by	Seals

Remarks ....

FORM 13. -TEST IN SITU CARD. (5in. by 3in.)

Address ....

Name ....

Station..........................

Voltage..........................

Meter Rent per Quarter } ....

LAMPS.							METER.								Remarks.
Advice.	Date.	8 c.p.	16 c.p.	Sundry.	Arcs.	Equivt. in 30 watt	Make.	Amps.	Number.	Date of Erection.	Advice.	Date taken down.	Advice.		

Date of Inspection.	Meter Reading.	Consumption.	Units Chargeable.	Rate.	Charges.		Remarks.
					For Current.	Meter Rent.	

FORM 14.—CONSUMER'S LEDGER CARD. (10in. by 8in.)

TABLE OF DOUBLED SQUARE ROOTS FO

	0	100	200	300	400	500	600	700	800	900	
0	0·000	20·00	28·28	34·64	40·00	44·72	48·99	52·92	56·57	60·00	0
1	2·000	20·10	28·35	34·70	40·05	44·77	49·03	52·95	56·60	60·03	1
2	2·828	20·20	28·43	34·76	40·10	44·81	49·07	52·99	56·64	60·07	2
3	3·464	20·30	28·50	34·81	40·15	44·86	49·11	53·03	56·67	60·10	3
4	4·000	20·40	28·57	34·87	40·20	44·90	49·15	53·07	56·71	60·13	4
5	4·472	20·49	28·64	34·93	40·25	44·94	49·19	53·10	56·75	60·17	5
6	4·899	20·59	28·71	34·99	40·30	44·99	49·23	53·14	56·78	60·20	6
7	5·292	20·69	28·77	35·04	40·35	45·03	49·27	53·18	56·82	60·23	7
8	5·657	20·78	28·84	35·10	40·40	45·08	49·32	53·22	56·85	60·27	8
9	6·000	20·88	28·91	35·16	40·45	45·12	49·36	53·25	56·89	60·30	9
10	6·325	20·98	28·98	35·21	40·50	45·17	49·40	53·29	56·92	60·33	10
11	6·633	21·07	29·05	35·27	40·55	45·21	49·44	53·33	56·96	60·37	11
12	6·928	21·17	29·12	35·33	40·60	45·25	49·48	53·37	56·99	60·40	12
13	7·211	21·26	29·19	35·38	40·64	45·30	49·52	53·40	57·03	60·43	13
14	7·483	21·35	29·26	35·44	40·69	45·34	49·56	53·44	57·06	60·46	14
15	7·746	21·45	29·33	35·50	40·74	45·39	49·60	53·48	57·10	60·50	15
16	8·000	21·54	29·39	35·55	40·79	45·43	49·64	53·52	57·13	60·53	16
17	8·246	21·63	29·46	35·61	40·84	45·48	49·68	53·55	57·17	60·56	17
18	8·485	21·73	29·53	35·67	40·89	45·52	49·72	53·59	57·20	60·60	18
19	8·718	21·82	29·60	35·72	40·94	45·56	49·76	53·63	57·24	60·63	19
20	8·944	21·91	29·66	35·78	40·99	45·61	49·80	53·67	57·27	60·66	20
21	9·165	22·00	29·73	35·83	41·04	45·65	49.84	53·70	57·31	60·70	21
22	9·381	22·09	29·80	35·89	41·09	45·69	49·88	53·74	57·34	60·73	22
23	9·592	22·18	29·87	35·94	41·13	45·74	49·92	53·78	57·38	60·76	23
24	9·798	22·27	29·93	36·00	41·18	45·78	49·96	53·81	57·41	60·79	24
25	10·000	22·36	30·00	36·06	41·23	45·83	50·00	53·85	57·45	60·83	25
26	10·198	22·45	30·07	36·11	41·28	45·87	50·04	53·89	57.48	60·86	26
27	10·392	22·54	30·13	36·17	41·33	45·91	50·08	53·93	57·52	60·89	27
28	10·583	22·63	30·20	36·22	41·38	45·96	50·12	53·96	57·55	60·93	28
29	10·770	22·72	30·27	36·28	41·42	46·00	50·16	54·00	57·58	60·96	29
30	10·954	22·80	30·33	36·33	41·47	46·04	50·20	54·04	57·62	60·99	30
31	11·136	22·89	30·40	36·39	41·52	46·09	50·24	54·07	57·65	61·02	31
32	11·314	22·98	30·46	36·44	41·57	46·13	50·28	54·11	57·69	61·06	32
33	11·489	23·07	30·53	36·50	41·62	46·17	50·32	54·15	57·72	61·09	33
34	11·662	23·15	30·59	36·55	41·67	46·22	50·36	54·18	57·76	61·12	34
35	11·832	23·24	30·66	36·61	41·71	46·26	50·40	54·22	57·79	61·16	35
36	12·000	23·32	30·72	36·66	41·76	46·30	50·44	54·26	57·83	61·19	36
37	12·166	23·41	30·79	36·72	41·81	46·35	50·48	54·30	57·86	61·22	37
38	12·329	23·49	30·85	36·77	41·86	46·39	50·52	54·33	57·90	61·25	38
39	12·490	23·58	30·92	36·82	41·90	46·43	50·56	54·37	57·93	61·29	39
40	12·649	23·66	30·98	36·88	41·95	46·48	50·60	54·41	57·97	61·32	40
41	12·806	23·75	31·05	36·93	42·00	46·52	50·64	54·44	58·00	61·35	41
42	12·961	23·83	31·11	36·99	42·05	46·56	50·68	54·48	58·03	61·38	42
43	13·115	23·92	31·18	37·04	42·10	46·60	50·71	54·52	58·07	61·42	43
44	13·266	24·00	31·24	37·09	42·14	46·65	50·75	54·55	58·10	61·45	44
45	13·416	24·08	31·30	37·15	42·19	46·69	50·79	54·59	58·14	61·48	45
46	13·565	24·17	31·37	37·20	42·24	46·73	50·83	54·63	58·17	61·51	46
47	13·711	24·25	31·43	37·26	42·28	46·78	50·87	54·66	58·21	61·55	47
48	13·856	24·33	31·50	37·31	42·33	46.82	50·91	54·70	58·24	61·58	48
49	14·000	24·41	31·56	37·36	42·38	46·86	50·95	54·74	58·28	61·61	49
50	14·142	24·49	31·62	37·42	42·43	46·90	50·99	54·77	58·31	61·64	50

	0	100	200	300	400	500	600	700	800	900	
51	14·283	24·58	31·69	37·47	42·47	46·95	51·03	54·81	58·34	61·68	51
52	14·422	24·66	31·75	37·52	42·52	46·99	51·07	54·85	58·38	61·71	52
53	14·560	24·74	31·81	37·58	42·57	47·03	51·11	54·88	58·41	61·74	53
54	14·697	24·82	31·87	37·63	42·61	47·07	51·15	54·92	58·45	61·77	54
55	14·832	24·90	31·94	37·68	42·66	47·12	51·19	54·95	58·48	61·81	55
56	14·967	24·98	32·00	37·74	42·71	47·16	51·22	54·99	58·51	61·84	56
57	15·100	25·06	32·06	37·79	42·76	47·20	51·26	55·03	58·55	61·87	57
58	15·232	25·14	32·12	37·84	42·80	47·24	51·30	55·06	58·58	61·90	58
59	15·362	25·22	32·19	37·89	42·85	47·29	51·34	55·10	58·62	61·94	59
60	15·492	25·30	32·25	37·95	42·90	47·33	51·38	55·14	58·65	61·97	60
61	15·620	25·38	32·31	38·00	42·94	47·37	51·42	55·17	58·69	62·00	61
62	15·748	25·46	32·37	38·05	42·99	47·41	51·46	55·21	58·72	62·03	62
63	15·875	25·53	32·43	38·11	43·03	47·46	51·50	55·24	58·75	62·06	63
64	16·000	25·61	32·50	38·16	43·08	47·50	51·54	55·28	58·79	62·10	64
65	16·125	25·69	32·56	38·21	43·13	47·54	51·58	55·32	58·82	62·13	65
66	16·248	25·77	32·62	38·26	43·17	47·58	51·61	55·35	58·86	62·16	66
67	16·371	25·85	32·68	38·31	43·22	47·62	51·65	55·39	58·89	62·19	67
68	16·492	25·92	32·74	38·37	43·27	47·67	51·69	55·43	58·92	62·23	68
69	16·613	26·00	32·80	38·42	43·31	47·71	51·73	55·46	58·96	62·26	69
70	16·733	26·08	32·86	38·47	43·36	47·75	51·77	55·50	58·99	62·29	70
71	16·852	26·15	32·92	38·52	43·41	47·79	51·81	55·53	59·03	62·32	71
72	16·971	26·23	32·98	38·57	43·45	47·83	51·85	55·57	59·06	62·35	72
73	17·088	26·31	33·05	38·63	43·50	47·87	51·88	55·61	59·09	62·39	73
74	17·205	26·38	33·11	38·68	43·54	47·92	51·92	55·64	59·13	62·42	74
75	17·321	26·46	33·17	38·73	43·59	47·96	51·96	55·68	59·16	62·45	75
76	17·436	26·53	33·23	38·78	43·63	48·00	52·00	55·71	59·19	62·48	76
77	17·550	26·61	33·29	38·83	43·68	48·04	52·04	55·75	59·23	62·51	77
78	17·664	26·68	33·35	38·88	43·73	48·08	52·08	55·79	59·26	62·55	78
79	17·776	26·76	33·41	38·94	43·77	48·12	52·12	55·82	59·30	62·58	79
80	17·889	26·83	33·47	38·99	43·82	48·17	52·15	55·86	59·33	62·61	80
81	18·000	26·91	33·53	39·04	43·86	48·21	52·19	55·89	59·36	62·64	81
82	18·111	26·98	33·59	39·09	43·91	48·25	52·23	55·93	59·40	62·67	82
83	18·221	27·06	33·65	39·14	43·95	48·29	52·27	55·96	59·43	62·71	83
84	18·330	27·13	33·70	39·19	44·00	48·33	52·31	56·00	59·46	62·74	84
85	18·439	27·20	33·76	39·24	44·05	48·37	52·35	56·04	59·50	62·77	85
86	18·547	27·28	33·82	39·29	44·09	48·41	52·38	56·07	59·53	62·80	86
87	18·655	27·35	33·88	39·34	44·14	48·46	52·42	56·11	59·57	62·83	87
88	18·762	27·42	33·94	39·40	44·18	48·50	52·46	56·14	59·60	62·86	88
89	18·868	27·50	34·00	39·45	44·23	48·54	52·50	56·18	59·63	62·90	89
90	18·974	27·57	34·06	39·50	44·27	48·58	52·54	56·21	59·67	62·93	90
91	19·079	27·64	34·12	39·55	44·32	48·62	52·57	56·25	59·70	62·96	91
92	19·183	27·71	34·18	39·60	44·36	48·66	52·61	56·28	59·73	62·99	92
93	19·287	27·78	34·23	39·65	44·41	48·70	52·65	56·32	59·77	63·02	93
94	19·391	27·86	34·29	39·70	44·45	48·74	52·69	56·36	59·80	63·06	94
95	19·494	27·93	34·35	39·75	44·50	48·79	52·73	56·39	59·83	63·09	95
96	19·596	28·00	34·41	39·80	44·54	48·83	52·76	56·43	59·87	63·12	96
97	19·698	28·07	34·47	39·85	44·59	48·87	52·80	56·46	59·90	63·15	97
98	19·799	28·14	34·53	39·90	44·63	48·91	52·84	56·50	59·93	63·18	98
99	19.900	28·21	34·58	39·95	44·68	48·95	52·88	56·53	59·97	63·21	99
100	20·000	28·28	34·64	40·00	44·72	48·99	52·92	56·57	60·00	63·25	100

METERS APPROVED BY THE BOARD OF TRADE.

Date of order of approval.	Name.	System of measuring.	Remarks.
Oct. 8, 1891 ...	Shallenberger	Alternate current ...	For use by the Metropolitan and House-to-House (now Brompton and Kensington Supply) Cos. only.
Oct. 28, 1896...	Ferranti	Quantity of continuous current at constant potential	Subject to arrangements that not more than 50% above intended maximum can be passed.
Oct. 28, 1896...	Hookham	Ditto	......
July 26, 1898	Aron	Energy of constant potential cont. cur.	......
March 23, 1899	Aron	Energy of alternating current at constant potential	......
July 12, 1899	Aron	Ditto	For two- or three-phase systems.
July 27, 1900	Bastian..................	Quantity of constant potential continuous current	......
May 17, 1901	Shallenberger A.C. watt-hour meter	Energy of constant potential alt. cur.	......
Sept. 24, 1901	Long Schattner	Prepayment meter for constant potential continuous current	Not exceeding 3 amps.
1901	Elihu-Thomson	Energy	......
Feb. 21, 1902	British Thomson-Houston Co. O.K. meter	Quantity of constant potential continuous current	Ditto
May 22, 1902	Hookham	Ditto	......
Sept. 24, 1902	Westinghouse watt-hour meter.	Energy of constant potential alt. cur.	......
July 9, 1903...	Atkinson Schattner	Maximum current for constant potential continuous or alternating system	This is not a meter but an indicator for use on the maximum demand system.
March 8, 1904	Stanley watt-hour meter	Energy of constant potential alternating current supply	......
May 12, 1904	Ferranti patent alternating current meter	Ditto	......
June 8, 1904	Wright's demand indicator	Same as Atkinson Schattner	......
Feb. 14, 1905	Bastian meter, N type, 1903 pattern	Electrical quantity for constant potential continuous current system	......
Feb. 27, 1905	E.C. alternating current watt-hour meter, Type K J ...	Electrical energy for constant potential alternating current system	......
Jan. 4, 1906	Aron motor meter ...	Ditto	......

In every case the method of fixing the meter is prescribed by the Order.

Notwithstanding the fact that so many meters have been approved, it appears from an answer given by the Board of Trade to the London County Council in October, 1901, that the Board are still of opinion that the time has not yet arrived for making the use of approved meters compulsory in all cases.

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AND

MANUFACTURERS' ANNOUNCEMENTS

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See also Advts. on pp. 340, 344, 346 and 348.

THE

HANBY

A.C. WATT-HOUR

METER

Distinguishes itself from all other Meters by only registering when energy passes and then registering permanently all that has passed.

It is light, neat, cheap, strong, durable, accurate, easily erected, read and maintained.

It has only five watts internal loss at full load, will carry **30** per cent. overload for four hours and is not affected by short circuits.

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Or NEWCASTLE, GLASGOW, or JOHANNESBURG.

BAT METERS.

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FOR

ACCURACY.

AT ELECTRICAL CO., 23 & 25, North St., King's Cross, LONDON

"WATSON" SLOT METER

For Alternating or Continuous Current.

No Liquids.

No Permanent Magnets.

No Mercury Contacts.

Cheating Proof.

Perfect Coin Trap.

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Cooper—PRIMARY BATTERIES: THEIR CONSTRUCTION AND USE. By W. R. Cooper, M.A. Fully Illustrated. Price 10s. 6d. nett.

Author's Preface—Extract.—Primary Batteries form a subject from which much has been hoped, and but little realised. But even so, it cannot be said that the advance has been small; and consequently no apology is offered for the present volume, in which the somewhat scattered literature of the subject has been brought together. Recent years have seen important additions to the theory of the voltaic cell, and therefore a considerable number of pages have been devoted to this part of the subject, although it is impossible to do more than give a superficial sketch of the theory in a volume like the present. With regard to the practical part of the subject, this volume is not intended to be encyclopædic in character; the object has been rather to describe those batteries which are in general use, or of particular theoretical interest. As far as possible, the Author has drawn on his personal experience, in giving practical results, which, it is hoped, will add to the usefulness of the book. Owing to the importance of the subject, Standard Cells have been dealt with at some length. Those cells, however, which are no longer in general use are not described; but recent work is summarised in some detail so as to give a fair idea of our knowledge up to the present time. It has also been thought well to devote a chapter to Carbon-Consuming Cells. Very little has been written upon this subject, but it is of great interest, and possibly of great importance in the future.

Cooper—*See* "THE ELECTRICIAN" PRIMERS, Page 11.

Curtis-Hayward—A DIGEST OF THE LAW OF ELECTRIC LIGHTING, ELECTRIC TRACTION AND OTHER SUBJECTS. By A. C. Curtis-Hayward, B.A., A.I.E.E. Price 3s. 6d., post free. *Published annually in March.*

Being a full critical abstract of the Electric Lighting Acts, 1882 and 1889, of the Tramways Act, 1870, and of the documents issued from time to time by the Board of Trade dealing with Electric Lighting, Electric Traction, &c., including the Rules as to the procedure in connection with applications to the Light Railway Commissioners for Orders under the Light Railways Act, 1896, and forms of accounts for Board of Trade returns for Electricity Supply Undertakings. The Digest treats first of the manner in which persons desirous of supplying electricity must set to work, and then of their rights and obligations after obtaining Parliamentary powers; and gives in a succinct form information of great value to Local Authorities, Electric Light Contractors, &c., up to date. The Board of Trade Regulations as to the Supply of Electrical Energy, the London County Council Regulations as to Overhead Wires, Theatre Lighting, &c., together with the Bye-laws enforced in pursuance of Part II. of the Public Health Acts Amendment Act, 1890, by the various Urban Sanitary Authorities are also given.

Ewing—MAGNETIC INDUCTION IN IRON AND OTHER METALS. By Prof. J. A. Ewing, M.A., B.Sc., F.R.S., Professor of Mechanism and Applied Mechanics in the University of Cambridge. 382 pages, 173 Illustrations. Price 10s. 6d. nett. Third Edition, Second Issue.

Synopsis of Contents.—After an introductory chapter, which attempts to explain the fundamental ideas and the terminology, an account is given of the methods which are usually employed to measure the magnetic quality of metals. Examples are then quoted, showing the results of such measurements for various specimens of iron, steel, nickel and cobalt. A chapter on Magnetic Hysteresis follows, and then the distinctive features of induction by very weak and by very strong magnetic forces are separately described, with further description of experimental methods, and with additional numerical results. The influence of Temperature and the influence of Stress are next discussed. The conception of the Magnetic Circuit is then explained, and some account is given of experiments which are best elucidated by making use of this essentially modern method of treatment.

Fisher—THE POTENTIOMETER AND ITS ADJUNCTS. (A Universal System of Electrical Measurement.) By W. Clark Fisher. Price 6s. post free; abroad, 6s. 6d.

The extended use of the Potentiometer System of Electrical Measurement will, it is hoped, be sufficient excuse for the publication of this work, which, while dealing with the main instrument, its construction, use and capabilities, would necessarily be incomplete without similar treatment of the various apparatus which, as adjuncts, extend the range and usefulness of the whole system.

The engineer or practical man demands that he shall be shown results quickly, plainly and accurately with a minimum of trouble, understanding, and consequently "Time," and on that account prefers—like all good mechanics—to have one good instrument, which, once understood and easily manipulated, can be used in a variety of ways to suit his needs. It is to this fact, undoubtedly, that the "Potentiometer" method of measurement owes its popularity. Its accuracy is rarely, if ever, impugned. Measurements made by it are universally accepted amongst engineers, and it might be well termed a "universal" instrument in "universal" use.

Fisher and Darby—STUDENTS' GUIDE TO SUBMARINE CABLE TESTING. By H. K. C. Fisher and J. C. H. Darby. New and Enlarged Edition. Fully Illustrated. Price 7s. 5d. nett, post free; abroad, 8s.

The Authors of this book have, for some years past, been engaged in the practical work of Submarine Cable Testing in the Eastern Extension Telegraph Company's service, and have embodied their experience in a Guide for the use of those in the Telegraph Service who desire to qualify themselves for the examinations which the Cable Companies have recently instituted. To those desirous of entering the Cable Service, Messrs. Fisher and Darby's book is indispensable, as it is now necessary for probationers to pass these examinations as part of the qualification for service.

A valuable set of Questions and Answers is added to the New and Enlarged Edition.

Fleming—A HANDBOOK FOR THE ELECTRICAL LABORATORY AND TESTING ROOM By Dr. J. A. Fleming, M.A., F.R.S., M.R.I., &c. Vol. I., price 12s. 6d. nett, post free 13s. Vol. II., 14s. nett.

This Handbook has been written especially to meet the requirements of Electrical Engineers in Supply Stations, Electrical Factories and Testing Rooms. The Book consists of a series of Chapters each describing the most approved and practical methods of conducting some one class of Electrical Measurements, such as those of Resistance, Electromotive Force, Current, Power, &c., &c. It does not contain merely an indiscriminate collection of Physical Laboratory, processes without regard to suitability for Engineering Work. The Author has brought to its compilation a long practical experience of the methods described, and it will be found to be a digest of the best experience in Electrical Testing. The Volumes contain a Chapter on the Equipment of Electrical Laboratories and numerous Tables of Electrical Data, which will render it an essential addition to the library of every practical Electrician, Teacher or Student.

SYNOPSIS OF CONTENTS.

Vol. I.

Chapter I.—Equipment of an Electrical Testing Room.
„ II.—The Measurement of Electrical Resistance.
„ III.—The Measurement of Electric Current.
„ IV.—The Measurement of Electromotive Force.
„ V.—The Measurement of Electric Power.

Vol. II.

Chapter I.—The Measurement of Electric Quantity and Energy.
„ II.—The Measurement of Capacity and Inductance.
„ III.—Photometry.
„ IV.—Magnetic and Iron Testing.
„ V.—Dynamo, Motor and Transformer Testing.

Fleming—THE ALTERNATE CURRENT TRANSFORMER IN THEORY AND PRACTICE. By J. A. Fleming, M.A., D.Sc., F.R.S., M.R.I., &c., Professor of Electrical Engineering in University College, London. Vol. I. New Edition—Almost entirely Rewritten, and brought up to date. More than 600 pages and 213 illustrations, 12s. 6d. post free; abroad, 13s.

Since the first edition of this Treatise was published, the study of the properties and applications of alternating electric currents has made enormous progress. . . . . The Author has, accordingly, rewritten the greater part of the chapters, and availed himself of various criticisms, with the desire of removing mistakes and remedying defects of treatment. In the hope that this will be found to render the book still useful to the increasing numbers of those who are practically engaged in alternating-current work, he has sought, as far as possible, to avoid academic methods and keep in touch with the necessities of the student who has to deal with the subject not as a basis for mathematical gymnastics but with the object of acquiring practically useful knowledge.

Dr. Fleming's manual on the Alternate-Current Transformer in Theory and Practice is recognised as the text book on the subject. Vol. I., which deals with "The Induction of Electric Currents," has passed through three editions, each edition having, in its turn, passed through several issues. This volume consists of 613 pages, and has 213 illustrations.

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Vol. II. treats of "The Utilisation of Induced Currents." This volume has also passed through numerous issues, consists of about 600 pages, and has 313 illustrations.

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These "Laboratory Notes and Forms" have been prepared to assist Teachers, Demonstrators, and Students in Electrical Laboratories, and to enable the Teacher to economise time. They consist of a series of (about) Twenty Elementary and (about) Twenty Advanced Exercises in Practical Electrical Measurements and Testing. For each of these Exercises a four-page Report Sheet has been prepared, two pages of which are occupied with a condensed account of the theory and practical instructions for performing the particular Experiment, the two other pages being ruled up in lettered columns, to be filled in by the Student with the observed and calculated quantities. When simple diagrams will assist the Student, these have been supplied. These Exercises are for the most part based on the methods in use in the Electrical Engineering Laboratories of University College, London; but they are perfectly general, and can be put into practice in any Electrical Laboratory.

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Fleming.—ELECTRIC LAMPS AND ELECTRIC LIGHTING.
By Prof. J. A. Fleming, M.A., D.Sc., F.R.S., M.R.I., Professor of Electrical Engineering in University College, London. New Edition. Very fully illustrated, handsomely bound, on good paper, price 6s. nett.

The original aim of a course of four lectures by Prof. J. A. Fleming on "Electric Illumination" was to offer to a general audience such non-technical explanations of the physical effects and problems concerned in the modern applications of electricity for illumination purposes as might serve to further an intelligent interest in the subject. In this, the second edition of the book, the author has brought the original edition into line with recent practice without departing from the elementary character of the work.

Fleming—THE ELECTRONIC THEORY OF ELECTRICITY.
By Prof. J. A. Fleming, M.A., D.Sc., F.R.S. Price 1s. 6d. post free.

Extract from the Author.—In this sketch of the Electronic Theory the author has made no attempt to present a detailed account of discoveries in their historical order, or to connect them especially with their authors. The object has been to show the evolution of the idea that electricity is atomic in structure, and that thus these atoms of electricity called electrons attach themselves to material atoms and are separable from them. Lorentz, Helmholtz, Thomson and others have shown that such a conception of atomic structure enables us to explain many electro-optic phenomena which are inexplicable on any other theory. The Electronic Theory of Electricity, which is an expansion of an idea originally due to Weber, does not invalidate the ideas which lie at the base of Maxwell's theory that electric and magnetic effects are due to the strains and stresses in the æther, but supplements them by a new conception—that of the electron or electric particle as the thing which is moved by electric force, and which, in turn, gives rise to magnetic force as it moves. All the facts of electricity and magnetism are capable of being restated in the terms of the idea.

Fleming—HERTZIAN WAVE WIRELESS TELEGRAPHY;
A Reprint of a series of articles in the "Popular Science Monthly," based upon Dr Fleming's Cantor Lectures before the Society of Arts, 1903. By Dr. J. A. Fleming, F.R.S. 108 large 8vo. pages, fully illustrated. 3s. 6d. nett.

Geipel and Kilgour—A POCKET-BOOK OF ELECTRICAL ENGINEERING FORMULÆ, &c. By W. Geipel and H. Kilgour. 800 pages. 7s. 6d. nett; post free at home or abroad, 7s. 9d.

With the extension of all branches of Electrical Engineering (and particularly the heavier branches), the need of a publication of the Pocket-Book style dealing practically therewith increases; for while there are many such books referring to Mechanical Engineering, and several dealing almost exclusively with the lighter branches of electrical work, none of these suffice for the purposes of the numerous body of Electrical Engineers engaged in the application of electricity to Lighting, Traction, Transmission of Power, Metallurgy, and Chemical Manufacturing. It is to supply this real want that this most comprehensive book has been prepared.

Compiled to some extent on the lines of other pocket-books, the rules and formulæ in general use among Electricians and Electrical Engineers all over the world have been supplemented by brief and, it is hoped, clear descriptions of the various subjects treated, as well as by concise articles and hints on the construction and management of various plant and machinery.

No pains have been spared in compiling the various sections to bring the book thoroughly up to date; and while much original matter is given, that which is not original has been carefully selected, and, where necessary, corrected. Where authorities differ, as far as practicable a mean has been taken, the different formulæ being quoted for guidance.

Gerhardi—ELECTRICITY METERS, THEIR CONSTRUCTION AND MANAGEMENT. A Practical Manual for Central Station Engineers, Distributing Engineers, and Students. By C. H. W. Gerhardi. 8vo. Very fully illustrated. *Now Ready.* 9s. nett.

This valuable Practical Manual on the Management of Electricity Meters, which will form a volume in "THE ELECTRICIAN" Series, will be published shortly. The Author has had many years' exceptional experience with Electricity Meters as chief of the Testing Department of the largest electricity supply undertaking in the United Kingdom. Mr. Gerhardi's intimate acquaintance with the working of all existing meters on the market, and with the details of their construction, is a guarantee that the book will meet the requirements of those engaged in work in which the Electricity Meter forms an essential part. In the division of the book devoted to "Testing," Mr. Gerhardi's experience will prove of the greatest service to supply station engineers and managers.

Gore—THE ART OF ELECTROLYTIC SEPARATION OF METALS (Theoretical and Practical). By George Gore, LL.D., F.R.S. The only book on this important subject in any language. Over 300 pages, 106 illustrations. Price 10s. 6d. post free.

No other book entirely devoted to the Electrolytic Separation of Metals exists in any language, those dealing with electro-metallurgy being all more or less devoted to electro-plating. Dr. Gore's work is, therefore, of the utmost service in connection with all classes of electrolytic work connected with the refining of metals. The book contains both the science and the art of the subject (both the theoretical principles upon which the art is based and the practical rules and details of technical application on a commercial scale), so that it is suited to the requirements of both students and manufacturers.

Gore—ELECTRO-CHEMISTRY. By George Gore, LL.D., F.R.S.
Second Edition. Price 2s. post free.

At the time when this book first appeared no separate treatise on Electro-Chemistry existed in the English language, and Dr. Gore, whose books on electro-metallurgy, electro-deposition and other important branches of electro-technical work are known throughout the world, has collected together a mass of useful information and has arranged this in consecutive order, giving brief descriptions of the known laws and general principles which underlie the subject of Electro-Chemistry. A very copious index is provided.

Hawkins—THE THEORY OF COMMUTATION By C. C. Hawkins, M.A., M.I.E.E. Paper covers. 2s. 6d. nett.

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The first twelve articles of Vol. I. deal mainly with Telegraphy, and the next eight with the Theory of the Propagation of Variations of Current along Wires. Then follows a series of Papers relating to Electrical Theory in general.

The contents of Vol. II. include numerous Papers on Electro-Magnetic Induct on and its Propagation, on the Self-Induction of Wires, on Resistance and Conductance Operators and their Derivatives Inductance and Permittance, on Electro-Magnetic Waves, a general solution of Maxwell's Electro-Magnetic Equations in a Homogeneous Isotropic Medium, Notes on Nomenclature, on the Theory of the Telephone, on Hysteresis, Lightning Conductors, &c.

These two Volumes are scarce and are not likely to be reprinted.

Heaviside—ELECTROMAGNETIC THEORY. By Oliver Heaviside. Vol. I. Second issue. 466 pages. Price 12s. 6d., post free 13s. Vol. II. 568 pages. Price 12s. 6d. post free; abroad, 13s.

Extract from Preface to Vol. I.—This work is something approaching a connected treatise on electrical theory, though without the strict formality usually associated with a treatise. The following are some of the leading points in this volume. The first chapter is introductory. The second consists of an outline scheme of the fundamentals of electromagnetic theory from the Faraday-Maxwell point of view, with some small modifications and extensions upon Maxwell's equations. The third chapter is devoted to vector algebra and analysis, in the form used by me in former papers. The fourth chapter is devoted to the theory of plane electromagnetic waves, and, being mainly descriptive, may perhaps be read with profit by many who are unable to tackle the mathematical theory comprehensively. I have included in the present volume the application of the theory (in duplex form) to straight wires, and also an account of the effects of self-induction and leakage, which are of some significance in present practice as well as in possible future developments.

Extract from Preface to Vol. II.—From one point of view this volume consists essentially of a detailed development of the mathematical theory of the propagation of plane electromagnetic waves in conducting dielectrics, according to Maxwell's theory, somewhat extended. From another point of view, it is the development of the theory of the propagation of waves along wires. But on account of the important applications, ranging from Atlantic telegraphy, through ordinary telegraphy and telephony, to Hertzian waves along wires, the Author has usually preferred to express results in terms of the concrete voltage and current, rather than the specific electric and magnetic forces belonging to a single tube of flux of energy. . . . The theory of the latest kind of so-called wireless telegraphy (Lodge, Marconi, &c.) has been somewhat anticipated, since the waves sent up the vertical wire are hemispherical, with their equatorial bases on the ground or sea, which they run along in expanding. (*See* § 60, Vol. I.; *also* § 393 in this volume.) The author's old predictions relating to skin conduction, and to the possibilities of long-distance telephony have been abundantly verified in advancing practice; and his old predictions relating to the behaviour of approximately distortionless circuits have also received fair support in the quantitative observation of Hertzian waves along wires.

Vol. III. in preparation, ready in 1906.

Jehl—CARBON MAKING FOR ALL ELECTRICAL PURPOSES. By Francis Jehl. Fully illustrated. Price 10s. 6d. post free.

This work gives a concise account of the process of making High Grade and other Carbon for Electric Lighting, Electrolytic, and all other electrical purposes.

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These instructive Practical Notes for Electrical Students were started by Mr. A. E. Kennelly prior to his departure from England to join the staff of Mr. Edison in the United States, and were continued and completed by Mr. H. D. Wilkinson, who has prepared a work which is of great service to students. The volume contains 155 illustrations, and deals mainly with Laws, Units and Simple Measuring Apparatus.

Lemström—ELECTRICITY IN AGRICULTURE AND HORTICULTURE. By Prof. S. Lemström. With illustrations. Price 3s. 6d. nett.

Extract from Author's Introductory Remarks.—It is well known that the question which is the subject of this book has been a favourite field of investigation for a century past. As the subject is connected with no less than three sciences—viz., physics, botany and agricultural physics—it is in itself not particularly attractive. The causes which induced me to begin the investigation of this matter were manifold, and I venture to hope that an exposition of them will not be without general interest.

Lodge—WIRELESS TELEGRAPHY.—SIGNALLING ACROSS SPACE WITHOUT WIRES. By Sir Oliver J. Lodge, D.Sc., F.R.S. New and Enlarged Edition. Second Issue. Very fully illustrated. Price 5s. nett, post free 5s. 3d.

The new edition forms a complete Illustrated Treatise on Hertzian Wave Work. The Full Notes of the interesting Lecture delivered by the Author before the Royal Institution, London, in June, 1894, form the first chapter of the book. The second chapter is devoted to the Application of Hertz Waves and Coherer Signalling to Telegraphy, while Chapter III. gives Details of other Telegraphic Developments. In Chapter IV. a history of the Coherer Principle is given, including Professor Hughes' Early Observations before Hertz or Branly, and the work of M. Branly. Chapters are also devoted to "Communications with respect to Coherer Phenomena on a Large Scale," the "Photo-Electric Researches of Drs. Elster and Geitel," and the Photo-Electric Researches of Prof. Righi.

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Pritchard—THE MANUFACTURE OF ELECTRIC LIGHT CARBONS. By O. G. Pritchard. A Practical Guide to the Establishment of a Carbon Manufactory. Fully illustrated. Price 1s. 6d., post free 1s. 9d.

The object of Mr. Pritchard in preparing this work for publication was to enable British manufacturers to compete with those of France, Austria, Germany and Bohemia in the production of electric arc carbon candles. The book is fully illustrated and gives technical details or the establishment and working of a complete carbon factory.

Ram—THE INCANDESCENT LAMP AND ITS MANUFACTURE. By Gilbert S. Ram. Fully Illustrated. Price 7s. 6d. post free.

The Author has endeavoured to give such information as he has acquired in the course of a considerable experience in Lamp-making, and to present that information with as little mathematical embellishment as possible. The subjects dealt with include:—The Filament: Preparation of the Filament, Carbonising, Mounting, Flashing, Sizes of Filaments, Measuring the Filaments; Glass Making and Blowing, Sealing-in, Exhausting, Testing, Capping, Efficiency and Duration, and Relation between Light and Power.

Raphael—THE LOCALISATION OF FAULTS IN ELECTRIC LIGHT MAINS. By F. Charles Raphael. New Edition. Price 7s. 6d. nett.

Although the localisation of faults in telegraph cables has been dealt with fully in several hand-books and pocket-books, the treatment of faulty electric light and power cables has never been discussed in an equally comprehensive manner. The conditions of the problems are, however, very different in the two cases; faults in telegraph cables are seldom localised before their resistance has become low compared with the resistance of the cable itself, while in electric light work the contrary almost always obtains. This fact alone entirely changes the method of treatment required in the latter case, and it has been the Author's endeavour, by dealing with the matter systematically, and as a separate subject, to adequately fill a gap which has hitherto existed in technical literature.

The various methods of insulation testing during working have been collected and discussed, as these tests may be considered to belong to the subject.

Raphael—"THE ELECTRICIAN" WIREMAN'S POCKET-BOOK. A Manual for the Wiring Contractor, the Mains Superintendent and the Wireman. Edited by F. Charles Raphael. Price 5s. nett, post free 5s. 3d. *New Edition nearly ready.*

EDITOR'S NOTE.—When the preparation of this Pocket-Book was commenced, the original intention of its Editor was to collect in a handy and useful form such Tables, Instructions and Memoranda as would be useful to the Electric Light Wireman in his work. This has been carried out in Section A of the Pocket-Book. During the past few years, however, many inquiries have been received for a good book dealing with the laying of underground mains, and with matters connected with insulated conductors generally. It was decided, therefore, to extend greatly the area covered by the book, and to treat the whole subject of erecting and laying electrical and conducting systems in such a manner that the tables, diagrams and letterpress might be useful to engineers in charge of such work, as well as to the wireman, jointer, and foreman. In fact, the section on Underground Work has been compiled largely with a view to meeting the requirements of Mains Superintendents, Central Station Engineers, and those occupied in designing networks.

In addition to the tables, instructions and other detailed information as to cables, ducts, junction boxes, &c.. contained in the section on Underground Mains, it has been deemed advisable to add a chapter briefly describing the various systems employed for public distributing networks. In this, essential practical information is alone given; two and three-phase systems are dealt with, as well as continuous current and single phase, and the method of calculating the size of the conductors and the fall of pressure from the number of lamps or horse-power of motors is made clear without the elaboration of clock-face diagrams or algebraical exercises.

Diagrams for the connections of telephones are given in Section D, including those for subscribers' instruments on the British Post Office exchange system in London; and it is believed that neither these diagrams nor those for bell connections have hitherto been published together in convenient pocket-book form. The various conversion factors in the Miscellaneous Section and the arrangement of the wages table are those which the Editor has himself found the most useful in practice.

Snell—ELECTRIC MOTIVE POWER. By Albion T. Snell. Over 400 pages, nearly 250 illustrations. Price 12s. 6d. post free; abroad, 13s.

The rapid spread of electrical work in collieries, mines and elsewhere has created a demand for a practical book on the subject of transmission of power. Though much had been written, there was no single work dealing with the question in a sufficiently comprehensive and yet practical manner to be of real use to the mechanical or mining engineer; either the treatment was adapted for specialists, or it was fragmentary, and power work was regarded as subservient to the question of lighting. The Author has felt the want of such a book in dealing with his clients and others, and in "ELECTRIC MOTIVE POWER" has endeavoured to supply it.

In the introduction the limiting conditions and essentials of a power plant are analysed, and in the subsequent chapters the power plant is treated synthetically. The dynamo, motor, line and details are discussed both as to function and design. The various systems of transmitting and distributing power by continuous and alternate currents are fully enlarged upon, and much practical information, gathered from actual experience, is distributed under the various divisions. The last two chapters deal exhaustively with the applications of electricity to mining work in Great Britain, the Continent and America, particularly with reference to collieries and coal-getting, and the results of the extensive experience gained in this field are embodied.

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